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Compiled by:

Patricia B. Plate

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HIGH-STRENGTH ALLOYS

51044 AN ELECTRON FRACTOGRAPHIC STUDY OF THE MECHANISMS OF DUCTILE RUPTURE IN METALS. C. D. Beachem, United States Naval Research Laboratory, Washington, D. C. NRL, Report 5871, December 31, 1962
(3 references, 17 pages, 19 figures)

Electron-microscopic examination of the topography of mechanically-produced fracture surfaces has shown that a large number of varied engineering metals fracture by a ductile-rupture process, including some tempered martensites that fracture in a macroscopically-brittle low-energy absorption manner. Since most ductile-rupture surfaces are composed largely of dimples from coalesced voids, a study of the coalescing processes was made. Depending on the local stress system imposed on the material surrounding the individual voids, coalescence may proceed in one of three manners—"normal rupture," "shear rupture," or "tearing." A detailed explanation of these mechanisms is presented.

51169 NONDESTRUCTIVE TESTING PROJECT. R. L. Lowery, Oklahoma State University, Stillwater, Oklahoma. Oklahoma City Air Materiel Area, Report No. 2, Contract No. AF 34(601)-9879, AD 291469
(numerous references, 377 pages, 27 figures)

Some methods of mechanical cleaning are suspected of polishing over cracks in jet engine compressor blades to such an extent that they cannot be detected by fluorescent-penetrant inspection. Therefore, it was required that a method be found whereby cracks of controlled magnitude could be induced into the compressor blades. These blades which are known to contain cracks can then be used to evaluate various cleaning-testing sequences.

Since the magnitude of the fatigue cracks was somewhat critical, it was required that the parameters involved in producing and detecting the cracks be subject to sensitive monitoring and control. As a number of fatigue-cracked blades would be needed, the time required to produce the desired fatigue cracks was also considered a factor in the choice of cracking methods.

The report outlines some of the fatigue cracking procedures considered and gives a detailed description of the equipment and procedure selected to produce and control fatigue cracks in compressor blades.

Cobalt Base

50866 See Columbium.

51073 See Engineering Steels.

Nickel Base

50866 See Columbium.

50919 INFLUENCE OF FLUORINE ENVIRONMENT ON THE MECHANICAL PROPERTIES OF SEVERAL SHEET ALLOYS. H. T. Richards and M. P. Hanson, Lewis Research Center, Cleveland, Ohio. NASA TN D-1706, Technical Note, April, 1963 (8 references, 14 pages, 5 figures, 2 tables)

The effect of a liquid-fluorine environment on the mechanical properties of several sheet alloys was investigated. The smooth and notch tensile strengths and the elongation properties of steel, nickel, aluminum, and titanium alloys were determined in liquid-nitrogen and liquid-fluorine environments (-320 F). Possible deterioration in the presence of fluorine and high stresses was detected by comparing the properties of alloys exposed to the two fluids at -320 F. The commercial-quality fluorine used contained contaminants.

50923 See Engineering Steels.

50967 CONTINUED INVESTIGATION OF AN ADVANCED-TEMPERATURE, TANTALUM-MODIFIED, NICKEL-BASE ALLOY. J. C. Freche and W. J. Waters, Lewis Research Center, Cleveland, Ohio. NASA TN D-1531, April, 1963 (17 references, 30 pages, 10 figures, 5 tables)

The investigation of an advanced-temperature, NASA nickel-base alloy having a nominal composition in weight per cent of 8 tantalum, 6 aluminum, 6 chromium, 4 molybdenum, 4 tungsten, 2.5 vanadium, 1 zirconium, 0.125 carbon, and balance nickel was continued.

The average ultimate tensile strength of the as-forged alloy ranged from 158,000 pounds per square inch at room temperature to 18,000 pounds per square inch at 2100 F. This compares with 135,000 and 34,000 pounds per square inch, respectively, for the as-cast alloy. Stress-rupture data obtained up to 2100 F at 15,000 pounds per square inch indicate average rupture lives for the as-cast alloy of 1000, 100, and 10 hours at 1817, 1915, and 2015 F, respectively. Impact tests provided evidence of alloy ductility. Additional evidence of workability was also obtained. Room-temperature forging, accomplished by unidirectional forging techniques, readily flattened 1/2-inch diameter, as-cast bars, and thickness reductions of 50 per cent were consistently obtained.

In oxidation tests at 1900 F, relatively low oxidation rates were obtained, although spalling of the oxide scale was observed upon cooling through the 800 to 600 F range. The weight gain per unit surface area for the NASA alloy was 2.9 and 6.5 milligrams per square centimeter after 50 and 200 hours exposure, respectively. These are not excessive oxidation rates, particularly for short-time applications; however, spalling may pose a problem in applications where frequent temperature cycling occurs.

51070 See Stainless Steels.

51073 See Engineering Steels.

51096 A NEW SERIES OF ADVANCED-TEMPERATURE NICKEL-BASE ALLOYS. J. C. Freche, W. J. Waters, and T. J. Riley, National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio. E-1229, paper presented for American Institute of Metallurgical Engineers, received April, 1963 (6 references, 15 pages, 5 figures, 3 tables)

Nickel-base alloys that do not require vacuum-melting techniques and that provide high-strength properties at elevated temperatures as well as a degree of workability were developed.

Both increased strength and workability were obtained by utilizing tantalum-alloying additions. The strongest alloy obtained in this investigation had a nominal composition in weight per cent of 8 tantalum, 6 chromium, 6 aluminum, 4 tungsten, 4 molybdenum, 2.5 vanadium, 1 zirconium, 0.125 carbon, and the balance nickel. This alloy demonstrated average as-cast rupture lives of 1200, 560, and 185 hours at 15,000-pounds per square inch stress and temperatures of 1800, 1850 and 1900 F, respectively. Ultimate tensile strengths of 80,000 54,300, and 49,200 pounds per square inch were obtained at 1800, 1900, and 2000 F. These results represent substantial improvements over the strongest previously developed alloy in this series.

Some workability was also demonstrated by limited rolling and forging attempts with this alloy. Buttons were rolled and reduced in thickness by 23 per cent at 1200 F without evidence of cracking. A 29 per cent change in the diameter of 0.75-inch forging bars was obtained by drop-forging at room temperature.

On the basis of the evaluations conducted, the strongest tantalum-modified alloy appears to have considerable potential for a variety of advanced-temperature applications, including structural members for aero-space vehicles.

Engineering Steels

50873 THE NOTCH PROPERTIES AND SHEAR TRANSITIONAL BEHAVIOR OF H11 STEEL. J. L. Sliney and F. Schmid, Watertown Arsenal Laboratories, Watertown, Massachusetts. WAL TR 766.5/2, Technical Report, February, 1963 (13 references, 27 pages, 10 figures, 11 tables)

A heat-treatment study was conducted on commercial, air-melted, 0.063-inch-thick H-11 steel sheet. Edge-notched tensile, center-notched crack propagation (G_c), and sheet Charpy impact specimens, which were tempered in the 600 F to 1100 F temperature range, all indicated the same general tempering behavior. Shear transition temperatures were determined as a function of sheet thickness (0.020 inch to 0.100 inch) using edge-notched tensile specimens ground to thickness from a 0.125-inch-thick sheet of H-11 steel after double tempering at 1075 F. Comments are made regarding relative toughness, fracture appearance, and the critical thickness concept as a function of test temperature. Steel sheet is not recommended for service use in thicknesses greater than the critical thickness at the lowest service temperature. Comments are included on the relative shear transitional behavior of air-melted and vacuum-melted H-11 and D6 steel sheet materials.

50875 THE HYDROGEN EMBRITTLEMENT SUSCEPTIBILITY OF TYPE H-11 STEEL AT HIGH STRENGTH LEVELS. E. J. Jankowsky, Naval Air Engineering Center, Philadelphia, Pennsylvania. Bureau of Naval Weapons, NAEC-AML-1637, Report, February 21, 1963
(2 references, 5 pages, 1 table)

An investigation of the effect of electrodeposition of cyanide cadmium on the sustained load-carrying capability of 5-chrome steel heat treated to 200, 220, and 240 ksi ultimate tensile strength levels is described.

H-11 steel is susceptible to hydrogen embrittlement at all strength levels of 210 ksi and above, and the loss in sustained load carrying capability becomes progressively higher as the strength level of the material increases.

50923 FATIGUE BEHAVIOR OF MATERIALS UNDER STRAIN CYCLING IN LOW AND INTERMEDIATE LIFE RANGE. R. W. Smith, M. H. Hirschberg, and S. S. Manson, Lewis Research Center, Cleveland, Ohio. NASA TN D-1574, Technical Note, April, 1963
(12 references, 56 pages, 15 figures, 6 tables)

A series of constant strain range tests was made for a wide variety of materials producing fatigue lives varying from a few cycles to about one million cycles. The specimens were subjected to axial, compression-tension, low-frequency fatigue about a zero mean strain. Load range was measured periodically throughout each test, enabling an analysis of fatigue results in terms of elastic, plastic, and total strains. Materials tested were AISI 4130 (soft and hard), AISI 4340 (annealed and hard), AISI 52100, AISI 304 ELC (annealed and hard), AISI 310 (annealed), AM 350 (annealed and hard), Inconel X, titanium (6Al-4V), 2014-T6, 5456-H311, and 1100 aluminum, and beryllium.

50926 See Titanium.

51009 STRIPLAP METHOD OF ROCKET MOTOR CASE FABRICATION. T. B. Card, Thiokol Chemical Corporation, Wasatch Division, Brigham City, Utah. ASD, ASD TR 7-912 (VII), Interim Technical Engineering Report, March, 1963, Contract No. AF 33(600)-42961
(13 pages, 4 figures, 2 tables)

Techniques have been developed for brazing steel strip to the TU-193 motor case end rings which provide the requisite bond strengths. The techniques require varying mandrel rotation speeds and controlling the application of heat at various points during brazing to the end rings. Work has also started on a program in which braze alloys melting in the 700 to 900 F range will be selected and tested.

51046 CHARACTERIZING FRACTURES BY ELECTRON FRACTOGRAPHY PART X. FRACTOGRAPHY OF NOTCH TENSILE SPECIMENS OF 4300-SERIES STEELS. A. J. Edwards and C. D. Beachem, United States Naval Research Laboratory, Washington, D. C. NRL, Memorandum Report 1394, February, 1963
(1 reference, 3 pages, 8 figures, 1 table)

Fracture faces of round-bar notch tensile specimens of five different 4300-series steels were examined in the electron microscope. The dependence of fracture mode on carbon content and relative yield strength level was investigated. A diagram is presented to show the dominant fracture modes observed for various combinations to yield strength and carbon content.

This report concludes the work on one phase of the problem; work on other aspects is continuing.

51073 HIGH TEMPERATURE MACHINING METHODS. I. A. Dickter, C. L. Mehl, and R. F. Henke, Cincinnati Milling Machine Company, Cincinnati, Ohio. ASD TDR 63-125, Final Report, January 23, 1963, Contract No. AF 33(600)-40066
(74 references, 360 pages, 204 figures)

Since 1957, The Cincinnati Milling Machine Co. has been conducting research to evaluate and develop hot machining techniques. This report describes the work on elevated temperature machining conducted over the last three years.

Hot machining can reduce the cost of manufacturing parts from many high-strength steels, precipitation-hardening stainless steels, and nickel- and cobalt-based alloys. Selection of parts with suitable materials, and proper planning of set-up and sequence of operations, materially influences the final cost. Manufacturing costs of aerospace parts when hot machined from heat treated AISI 4340 and Ph 15-7 Mo steels were reduced up to 36 per cent when compared to conventional machining.

Radio-frequency induction and resistance heating techniques were developed and proved practical for heating magnetic materials, while the inert tungsten arc torch was more satisfactory for non-magnetic materials.

51073 (Continued)

Most high strength metals will show a significant increase in tool life and permissible metal removal rates at elevated temperatures. Hot machining of 6 Al 4 V, 13V-11Cr-3Al titanium alloys and refractory metals and alloys, achieved only limited success.

While some metallurgical changes were observed on the hot machined nickel- and cobalt-based alloys, these changes were not severe or extensive.

No excessive safety or health hazards are involved.

51087 RESEARCH IN THE MECHANISM OF STRENGTHENING IN AUSFORMED STEEL. C. F. Martin, W. W. Gerberich, J. M. McCamont, and E. L. Harmon, Ford Motor Company, Aeronutronic Division, Newport Beach, California. ASD, ASD-TDR-62-692, Technical Documentary Report, February, 1963, Contract No. AF 33(616)-8116
(26 references, 98 pages, 48 figures, 5 tables)

This investigation was conducted to define the mechanism responsible for the strengthening increase imparted by deformation of metastable austenite. The relationships of mechanical properties to extent and temperature of deformation were developed for Type H-11 hot work die steel. The influence of nonmartensitic-decomposition products on ausformed properties was determined. The microstructures were studied by thin-film electron-transmission methods for observations of martensite morphology and substructures and precipitates. Measurements of subcell sizes and distribution of precipitates were made for comparison with observed mechanical properties through application of dislocation theory. The observed dislocation density and carbide dispersion indicate that the strengthening mechanism active in both ausformed and conventionally heat-treated martensitic steels is some combined effect of dislocation-precipitate and dislocation-dislocation interaction.

51093 INVESTIGATE THE EFFECT OF HIGH DYNAMIC PRESSURES UPON THE METALLURGICAL PROPERTIES OF IRON AND TITANIUM BASE ALLOYS. A. W. Hall, E. K. Henriksen, C. A. Landusky, and I. Lieberman, Aerojet-General Corporation, Ordnance Division, Downey, California. ASD, ASD-TDR-62-535, Technical Documentary Report, February, 1963, Contract No. AF 33(616)-8191
(28 references, 186 pages, numerous figures, numerous tables)

Effects of high dynamic pressures upon the metallurgical properties of iron- and titanium-base alloys are given. Pressure levels ranging from 86 kilobars to 390 kilobars were used to demonstrate refinement of structure with indications of ausforming in H-11 steel shocked at elevated temperature, a reduction in retained austenite for heat-treated and tempered UHB-46 steel, and an increase in susceptibility to aging for B120VCA titanium.

Metallurgical examinations of shocked specimens were conducted optically, with X-ray diffraction and with electron microscopy. Changes in hardness, structure, and dimensions were recorded and correlated with the pressures used. Hypotheses to explain the observed effects are presented.

51093 (Continued)

Details are presented pertinent to the explosive techniques developed for generating the dynamic shock, the recovery system employed to recover the specimens after shocking, and the problem areas associated with testing at elevated temperatures.

Recommendations for future work in specific areas selected as a result of the survey testing conducted under this program are presented.

51160 THE INFLUENCE OF TEMPERATURE AND STRAIN RATE ON CRACK TOUGHNESS OF MILD STEEL. A. K. Shoemaker, University of Illinois, Department of Theoretical and Applied Mechanics, Urbana, Illinois. Department of Army, T & AM Report No. 235, November, 1962, AD 291226, Contract No. DA-ARO(D)-31-124-G148
(35 pages, 24 figures, 1 table)

The purpose of this report is to show, using fracture-mechanics concepts, that the crack-toughness values of a low-carbon steel (four mild steels are examined in this report) vary according to a parameter which predicts the yield point for different combinations of temperature and strain rate. The analysis shows that the governing factor controlling the change in K_{Ic} is the change in plastic zone size at the crack tip which changes with the yield point. The yield point is controlled by the temperature and strain rate in the form of a parameter, $T \ell n A/\dot{\epsilon}$.

51167 METALLURGICAL PROPERTIES OF EXPLOSIVELY WORK-HARDENED STEELS. G. A. Hayes, United States Naval Ordnance Test Station, China Lake, California. NAVWEPS Report 8035, October, 1962, AD 291242
(20 references, 32 pages, 21 figures, 2 tables)

This report presents work-hardening data and a microstructural analysis indicating the changes in metallurgical properties that four steels (1015, 1030, 1050, and 4130) undergo when impulsively loaded with various amounts of high-energy explosive. The effects that steel-buffer thickness have on metallurgical properties are also presented.

Stainless Steels

50876 AGING RESPONSE OF 18% NI-CO-MO STEEL. S. V. Arnold, Watertown Arsenal Laboratories, Watertown, Massachusetts. WAL TR 320.1/11, February, 1963 (13 pages, 4 figures, 4 tables)

The 18 per cent Ni-Co-Mo steel has demonstrated excellent strength and toughness. Whereas no significant improvement was realized through heat treating by a practice differing from that recommended by International Nickel Company, the findings indicate considerable leeway is possible without impairing resultant properties. Toughness of the steel under impact is remarkably good, even to liquid-nitrogen temperatures. Sustained-load notched-tensile strength exceeds the 0.2 per cent yield strength by 40 to 50 per cent in the presence of a K_t = 6.3 notch. Tensile specimens stretched plastically various amounts and then fitted with such a notch showed no change in sustained-load notched-tensile strength, indicating the heat-treated material is stable and does not strain-age at ambient temperature.

50906 OPTICAL PROPERTIES OF SATELLITE MATERIALS — THE THEORY OF OPTICAL AND INFRARED PROPERTIES OF METALS. George C. Marshall Space Flight Center, Huntsville, Alabama. NASA TN D-1523, Technical Note, March, 1963, Contract No. DA-19-020-ORD-4857
(84 references, 253 pages, 51 figures, 14 tables)

This report is a consolidation of technical summaries on the optical properties of satellite materials prepared and tested by Arthur D. Little, Incorporated.

Chapter 1 presents the effect of satellite environment on the emissivity of material. Chapter 2 discusses the spectral emittance of polished stainless steel, aluminum, and magnesium at 50 C in the 0.25 - 28.0- micron wavelength region. Chapter 3 is devoted to the theory of optical and infrared properties of metals.

50921 See Composites.

50923 See Engineering Steels.

50926 See Titanium.

51070 MECHANICAL PROPERTIES OF HIGH-STRENGTH SHEET MATERIALS AT CRYOGENIC TEMPERATURES. J. L. Christian, General Dynamics Corporation, Astronautics, San Diego, California. ERR AN 255, November 28, 1962
(47 references, 73 pages, 9 figures, 22 tables)

The primary objective of this investigation was to determine the mechanical properties of several high-strength alloys at cryogenic temperatures. Another objective was to evaluate various test specimens and test methods to be used in determining the strength and toughness of materials at cryogenic temperatures. Mechanical properties were determined from 78 to -423 F on twenty different alloys which included stainless steels, nickel-titanium and aluminum-base alloys and several soft solders.

51070 (Continued)

The stainless steels reported herein include 55 and 75 per cent cold-rolled Type 202 and two heats of 70 per cent cold rolled Type 302, one heat of which was air melted; the other heat vacuum melted. The nickel-base alloys include Hastelloy alloy R-235, tested in the solution annealed and two aged conditions; four lots of electroformed nickel; thoria-dispersion-strengthened nickel (TD nickel); and two tempers, annealed and aged and cold-rolled-and-aged, of Inconel Alloy 718. The titanium alloy tested was Ti-8Al-1Mo-1V in the annealed condition. Aluminum alloys included 2024-T4, 7079-T6, and MD 75-T6, a new 7XXX series alloy developed by Reynolds Aluminum Company. Also, eight lead-tin base soft solders were evaluated and their tensile and shear properties from 78 to -423 F are reported.

Several test specimens and methods which were used for determination of materials' properties at cryogenic temperatures are presented and discussed.

51073 See Engineering Steels.

Iron Base

50866 See Columbium.

51138 PLATES MADE FROM 18% NICKEL MARAGING STEEL. Bethlehem Steel Company, Bethlehem, Pennsylvania. Metallurgical Report for Experiment No. 1452, April 16, 1963
(13 pages)

This report presents data on mechanical properties of plate made from 5 heats of 18 per cent Nickel Maraging steel. All plates were produced from electric furnace, vacuum degassed 7-ton heats. Rolled-plate thicknesses ranged from 0.307 inch to 2.500 inches.

Evaluation of data reveals that Maraging plate is capable of achieving yield strengths in excess of 250,000 psi (0.2 per cent offset) with correspondingly good ductility and toughness when given the optimum aging cycle.

51155 THE MANUFACTURE OF ROCKET MOTOR CASES FROM 18% NICKEL MAR-AGING STEEL. C. J. Bua, Wright Aeronautical Division, Curtiss-Wright Corporation, Wood-Ridge, New Jersey. Received March 19, 1963
(38 pages, 6 tables, numerous figures)

The objectives of this program were as follows: (1) to demonstrate the increased reliability of 18 per cent Nickel Mar-aging Steel over D6AC material and other ultra-high-strength material, (2) to achieve rocket-motor-case weight reduction without sacrificing design requirements or quality standards, (3) to demonstrate the feasibility of converting from D6AC material to 18 per cent Nickel in mid-production without additional tooling and a minimum of process changes, and (4) to show that substantial savings can be realized through simplified production techniques.

LIGHT METALS

50906 See Stainless Steels.

50923 See Engineering Steels.

51070 See Stainless Steels.

Beryllium

50923 See Engineering Steels.

51050 See Tungsten.

51168 CURRENT BERYLLIUM LITERATURE: A SELECTED BIBLIOGRAPHY JANUARY 1961 - DECEMBER 1962. University of California, Livermore, California. UCRL-5705 (Suppl.2), Bibliography, January, 1963, Contract No. W-7405-eng-48
(350 pages)

This bibliography is the result of a "current awareness" service performed by the American Society for Metals. The references were gathered from the world's leading journals, books, technical reports, dissertations, and patents for the period January, 1961, through December, 1962.

Titanium

50919 See Nickel Base.

50923 See Engineering Steels.

50926 RESEARCH AND APPLICATION ENGINEERING TO DETERMINE THE EFFECT OF PROCESSING VARIABLES ON CRACK PROPAGATION OF HIGH-STRENGTH STEELS AND TITANIUM. B. R. Banerjee and J. J. Hauser, Crucible Steel Company of America, Pittsburgh, Pennsylvania. ASD, ASD TDR 62-1034, Part I, December, 1962, Contract No. AF 33(616)-8156
(56 references, 137 pages, 70 figures, 18 tables)

This report describes in detail the fine-structural characterizing of several high-strength steels /AISI 4340, Type H-11 (Crucible 218), Type 422 stainless, work-hardened Type 301 stainless, PH15-7Mo semi-austenitic stainless, and B-120VCA beta titanium alloy/ and gives the relationship of these structures to smooth and notch strength properties. The fine structures of these materials were characterized and correlated with strength and fracture properties to an extent never before achieved.

50971 MECHANICAL SCALE REMOVAL FROM TITANIUM ALLOY SHEET. T. P. Broderick and G. M. Richmond, Titanium Metals Corporation of America, Toronto, Ohio. AMC, Interim Engineering Report No. 11, Phase IV, Contract No. AF 33(600)-37502
(8 pages, 1 figure, 3 tables)

Eight sheets of Ti-6Al-4V and Ti-4Al-3Mo-1V of various gauges were processed through the following sequence: (1) solution-treat in existing facilities to produce oxide coating, (2) descale on wire brush machine using "scotch-brite" process, (3) repeat steps 1 and 2 to confirm results, (4) grind with existing facilities and procedures, (5) polish with Scotch-brite process on wire brush machine, (6) repolish to duplicate one pass through four-stand machine.

Only two sheets of the original eight survived the complete sequence.

Both of the polished sheets were within mill specifications for minimum bend radius. One of the sheets achieved the ultimate bend capability; the other would have required additional polishing passes to approach this goal.

Considerable mechanical trouble was encountered during the course of testing.

It was concluded that solution-treated Ti-6Al-4V and Ti-4Al-3Mo-1V could be mechanically descaled before grinding using the "Scotch-brite" process, and that the same process could be used after grinding to condition the ground surface. Further, the Scotch-brite process is preferred over the wire brush and slurry process.

51008 DETERMINATION OF DESIGN DATA FOR HEAT TREATED TITANIUM ALLOY SHEET. D. L. White and H. T. Watson, Lockheed-Georgia Company, Marietta, Georgia. ASD, ASD-TDR-62-335 Vol 2b, Technical Documentary Report, December, 1962, Contract No. AF 33(616)-6346
(6 references, 358 pages, 502 figures, 8 tables)

51008 (Continued)

Mechanical and physical property data, necessary to fulfill the requirements of Phase II of the Department of Defense Titanium Alloy Sheet Rolling Program, were obtained for selected solution-treated-and-aged titanium alloys in sheet form.

Four alloys were investigated: B120VCA (Ti-13V-11Cr-3Al), Ti-6Al-4V, Ti-2.5Al-16V and Ti-4Al-3Mo-1V. They were supplied by the producers in the heat-treated condition from three or more heats and three thicknesses of each alloy. Static mechanical property data for tension, compression, bearing, shear, and crippling; creep and rupture data for tension, compression, bearing, and shear; and axial-load fatigue data were obtained at room and elevated temperatures. Fastener and weld joint data from -320 F to 80 F and physical properties from -420 F to 1200 F were obtained.

51070 See Stainless Steels.

51073 See Engineering Steels.

51093 See Engineering Steels.

51103 See Composites.

51165 A STUDY OF WELD HEAT-AFFECTED ZONES IN THE TITANIUM-6AL-6V-2SN ALLOY. R. E. Lewis and K. Wu, Watervliet Arsenal, Watervliet, New York. WVT 11-6215, Technical Report, September, 1962, AD 291400 (36 references, 40 pages, 21 figures)

A high-strength alpha-beta type titanium alloy was developed which is heat treatable to useful yield strengths above 180,000 pounds per square inch, with 7 per cent elongation, 16 per cent reduction in area, and 7 foot pounds Charpy V-notch impact energy at -40 F. Preliminary manual welding experience with this alloy disclosed a strong tendancy for cracking in the heat-affected zone. This study was performed to determine resultant toughness in the heat-affected zones for various welding conditions.

51201 PRELIMINARY RESULTS OF DIFFUSION STUDIES OF COMMERICALLY AVAILABLE COATINGS ON MO-0.5 TI MOLYBDENUM ALLOY SHEET AT 2500°F. B. A. Stein and W. B. Lisagor, Langley Research Center, National Aeronautics and Space Administration, Langley Field, Virginia. Paper prepared for the 7th Meeting of the Refractory Composites Working Group, Palo Alto, California. March 12-14, 1963 (1 reference, 17 pages, 7 figures, 2 tables)

The present study was undertaken: (1) to determine whether the coatings had embrittled the Mo-0.5 Ti sheet beyond the range of usefulness in the coating application; (2) to determine the magnitude of substrate loss due to solid-state diffusion during various exposures in air at 2500 F; (3) to obtain some insight into the mechanisms involved in the oxidation protection and solid-state diffusion processes by identification of the several phases present in the silicide-based coatings after 2500 F exposure in air.

Magnesium

50906 See Stainless Steels.

NONMETALLICS

50874 SUPERCONDUCTIVITY IN METALS AND ALLOYS. W. H. Cherry, G. D. Cody, J. L. Cooper, G. Cullen, J. I. Gittleman, J. J. Hanak, M. Rayl, and F. D. Rosi, Radio Corporation of America, Princeton, New Jersey. ASD, ASD-TDR-62-1111, Technical Documentary Report, February, 1963, Contract No. AF 33(657)-7733

Measurements were made of the Kapitza resistance in tin and indium and its change at the superconducting transition. For comparison with theory, measurements were also made on the insulator, sapphire. An attempt to detect an electric-field dependence of the Kapitza resistance in platinum had negative results.

A new method for the preparation of β -tungsten compound superconductors, such as Nb_3Sn, was developed. Both the properties of the deposited material and the extension of this method to such possible β -tungsten compounds as niobium germanide, niobium silicide, vanadium gallium, vanadium silicide, and niobium gallium are described.

The transition temperature of niobium stannide is shown to depend not only on the stoichiometry, but also on the state of order of the lattice. Resistivity of Nb_3Sn is given as a function of temperature from 4.2 K to 370 K.

Penetration depth measurements were made on deposited Nb_3Sn.

Quenching currents were measured on deposited Nb_3Sn.

Thermal conductivity measurements were made on Nb_3Sn. Preliminary results indicate qualitative agreement with the predictions of the microscopic theory of superconductivity.

In the Appendix, results are given from a study on the thermal effect of resistive current contacts on the quenching current of niobium stannide.

51203 PASSIVE THERMAL CONTROL COATINGS. J. E. Gilligan, M. E. Sibert, and T. A. Greening, Lockheed Missiles and Space Company, Palo Alto, California. Paper prepared for the 7th Meeting of the Refractory Composites Working Group, Palo Alto, California. March, 1963 (13 references, 40 pages, 11 figures, 10 tables)

Development of a unique class of coating-material systems for passive-temperature-control surfaces has been described. Certain alkali-silicate-based all-inorganic coating systems offer considerable promise for current long-term applications in this area of space technology. The major objective of this program has been the development of coating systems with stable α/ϵ values of less than 0.30 after 2,000 to 6,000 sun-hour exposures under space environmental conditions, with lesser emphasis in systems with α/ϵ values of up to 1.20.

Preliminary work indicated that coatings containing organic materials could not meet these requirements.

Carbon, Graphite

50937 CHARACTERISTIC TEMPERATURES AND THERMAL VIBRATIONS IN GRAPHITE AND DIAMOND AND THERMAL VIBRATIONS AND BONDING EFFECTS IN TITANIUM DIBORIDE. M. G. Miksic, Polytechnic Institute of Brooklyn, Brooklyn, New York. Technical Report No. 5, (Received April, 1963), Contract No. Nonr 839(12) (73 references, 101 pages, 16 figures, 15 tables)

X-ray measurements were made on a relatively good single crystal of graphite to determine the total atomic displacements from the layer planes at room temperature. Measurements made between room and liquid-nitrogen temperatures were analyzed by the Debye-Waller-expression to obtain values of the Debye characteristic temperature and amplitudes to thermal vibration. The lattice thermal expansion in the 'c' direction was also determined. An attempt was made to obtain a more accurate value of the thermal vibration amplitudes by considering a more exact frequency distribution for graphite.

An attempt to determine crystallographically any evidence of the postulated electron transfer, and, in addition, to obtain values of the characteristic temperature and amplitudes of thermal motion for each atomic species were undertaken using titanium diboride specimens.

51014 THE MAGNETIC SUSCEPTIBILITY OF PYROLYTIC CARBONS. D. B. Fischbach, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California. NASA, 32-165, Technical Report, March, 1963, Contract No. NAS 7-100
(10 pages, 5 figures, 2 tables)

The magnetic susceptibility of several oriented pyrolytic carbons (pyrolytic graphites) has been measured in the as-deposited condition, and after heat treatment at temperatures up to 3600 C. For pyrolytic carbons deposited at temperatures above 2000 C the susceptibility is substantially larger than that of single-crystal graphite. However, it obeys the electron gas temperature-dependence equation of Pacault and Marchand. Heat treatment at temperatures above the deposition temperature causes the anisotropic part of the susceptibility (measured at room temperature) to decrease to a minimum value after treatments near 2900 C before leveling out at the plateau value characteristic of graphite for heat treatment temperatures above 3100 C. The enhanced as-deposited susceptibility is attributed to the combination of large crystallite diameter and turbostratic structure observed in these materials. Possible causes of the susceptibility minimum are suggested. There is some evidence that the susceptibility behavior of pyrolytic carbons deposited at temperatures below 2000 C is similar to that usually observed in other pregraphite carbons.

51088 IMPROVEMENT OF THE USEFULNESS OF PYROLYTIC GRAPHITE IN ROCKET MOTOR APPLICATIONS. J. D. Batchelor, E. F. Ford, and E. L. Olcott, Atlantic Research Corporation, Alexandria, Virginia. United States Army, Final Technical Summary Report, February, 1963, Contract No. DA-36-034-ORD-3279Z
(96 pages, 31 figures, 7 tables)

51088 (Continued)

This research program consisted of a systematic study of the utility of pyrolytic graphite for service in uncooled nozzles for solid-propellant rocket motors. In an effort to improve the usefulness of pyrolytic graphite, studies were carried out in three areas. First, the effect of the deposition-process conditions on the nature of the pyrolytic-graphite coating formed was investigated. The pyrolytic graphite was characterized by density measurements, X-ray diffraction analysis, and microstructure examination. The deposition process was found sensitive to carbonaceous-source-gas concentration and local gas-flow conditions with a lesser effect of temperature above about 1900 C. Little effect of the type of source gas was noted. Below about 1900 C the deposits became increasingly coarse with decreased temperature. Of several substrate surface preparations and pretreatments only a resin precoat seemed to hold promise of improving the microstructure of lower temperature coatings.

The second area of study was mechanical design analysis to assure that good design practice was utilized. The basic stress-strain relationships were derived for an anisotropic material such as pyrolytic graphite. The shear stresses in a coated system were also examined. The segmented nozzle design utilized throughout the successful motor firing studies was found to meet the requirements of good design.

The third major area of study consisted of the experimental measurement in sub-scale rocket nozzle tests of the inherent erosion rate of a standard (2000 C) pyrolytic graphite under a variety of motor operating conditions. Tests were made with propellants having flame temperatures from 5600 F to 6500 F and a range of oxidation ratios. For a given propellant the erosion rate was a function of the motor operating pressure. Over the range studied, propellant flame temperature was found more significant than oxidation ratio in determining the erosion rate. The performance of pyrolytic-graphite coatings was excellent in all propellants at all motor pressures. Scale up from 0.5-inch test nozzles to a 1.0-inch-diameter nozzle was successfully accomplished and proved in full duration, high-pressure motor test. A 2.0-inch nozzle was designed and successfully fabricated prior to expiration of the contract funds.

51119 THERMAL STRESSES IN PYROLYTIC GRAPHITE. S. Levy, General Electric Company, Schenectady, New York. No. 2921-63, paper presented at the AIAA Launch and Space Vehicle Shell Structures Conference, Palm Springs, California. April 1-3, 1963
(10 pages, 3 figures)

Consideration is given to thermal stresses in pyrolytic graphite due to temperature changes and anisotropy. Formulas are derived for the stresses in spheres and cylinders. These show that uniform temperature changes, as well as gradients in the temperature and in the modulus, affect the final stress distribution. The formulas are limited to those problems where the temperature and modulus can be expressed as a power of the radius.

Equations are also presented for secondary anisotropy effects due to mandrel "contouring" and "nodules".

51120 A NOTE ON THE STRUCTURE-PROPERTY RELATIONSHIPS FOR PYROLYTIC GRAPHITE.
L. F. Coffin, Jr., General Electric Research Laboratory, Schenectady, New York. No. 2922-63, paper presented at the AIAA Launch and Space Vehicle Shell Structures Conference, Palm Springs, California. April 1-3, 1963
(10 pages, 15 figures, 1 table)

The mechanical and physical properties of pyrolytic graphite are closely related to the structure produced during its deposition. In the present report, it is shown how various features of the deposited structure can be predicted with some accuracy. These include the structure of isolated nodules, the influence of various substrate conditions, and effects of continuous nucleation. The role of these structures on properties is discussed, and in particular, the relationship of the residual stress state to the deposition conditions is explained.

Special Refractories

50920 REFRACTORY BINARY BORIDES. B. Post, Polytechnic Institute of Brooklyn, Brooklyn, New York. Technical Report No. 6, (Received April, 1963), Contract No. Nonr 839(12)
(150 references, 52 pages, 15 figures, 14 tables)

Boron forms binary borides with a large number of metals and non-metals; their compositions range from Me_4B through MeB_{12} to some recently reported MeB_{70} phases. These cannot be classified simply in terms of the usual chemical or metallurgical rules.

The classification of borides is discussed in Section I.

In Section II the crystal chemistry of the borides is discussed, followed by a description of binary borides of non-metals. The types of borides, classified according to the positions of the parent metals in the Periodic Table are further discussed in Section III. Electrical, magnetic and other properties are dealt with in Section IV.

50937 See Carbon, Graphite.

50975 A STUDY OF FUNDAMENTAL MECHANICAL PROPERTIES OF CERAMIC SINGLE CRYSTALS. P. T. B. Shaffer and H. D. Batha, The Carborundum Corporation, Niagara Falls, New York. Bureau of Naval Weapons, 1st Bi-Monthly Progress Report, March 25, 1963, Contract No. N600(19)-59749
(4 pages, 1 figure, 1 table)

Measurement of cross-bending strength and Young's modulus of pure silicon carbide has been carried out on approximately twenty-five samples at room temperature.

Construction of apparatus to extend strength and elasticity measurements to very thin ($< .0.001$ inch) crystals is complete.

51022 DISLOCATION MOBILITY AND PINNING IN HARD MATERIALS THROUGH INTERNAL FRICTION STUDIES. P. D. Southgate, Armour Research Foundation, Chicago, Illinois. ASD, ASD-TDR-62-431, Technical Documentary Report, February, 1963, Contract No. AF 33(616)-8132
(23 references, 87 pages, 36 figures, 3 tables)

The internal friction of covalently-bonded and partly covalently-bonded materials is being investigated at elevated temperatures. The apparatus operates on the electrostatic-drive system, and covers the range 0 to 1500 C, 1 to 200 kilocycles per second. Single crystals of silicon, silicon carbide, and zinc oxide have been measured. A steady rise of internal friction is seen in deformed silicon specimens above 500 C, which appears to be thermally activated with an activation energy of 1.61 + 0.02 electron volts. The rise is attributed to the dislocation damping; its magnitude is approximately proportional to the dislocation density and inversely to the frequency. Quantitative identification can be made with Brailsford's abrupt-kink theory of dislocation damping if a reasonable kink density is assumed, in which case the activation energy is that of kink mobility.

Observations of creep rate during deformation of silicon crystals at 950 C give rather variable results. The most common situation is that of approximately logarithmic creep, followed by some work hardening.

51022 (Continued)

Deviations occur in the form of an incubation time for creep, of a continuously increasing creep rate. Specimen orientation and oxygen content did not seem to have a major effect on behavior.

Silicon carbide and zinc oxide were measured only in the undeformed state. A number of peaks were seen in zinc oxide (29 kilocycles per second) at 135, 190 and 345 C, and in silicon carbide (110 kilocycles per second) at 500 C. Rapid rises in internal friction occurred above 750 in zinc oxide and 900 in silicon carbide. The peaks are too wide to be caused by simple point defect relaxation, and further data are required to identify them. The general annealing behavior of the rise in silicon carbide is very similar to that in an anomalous silicon specimen having a very non-uniform dislocation distribution.

51052 BENCH SCALE STUDIES ON HIGH TEMPERATURE MATERIALS COMPATIBILITY. V. L. Hill and R. H. Singleton, Allison Division, General Motors Corporation, Indianapolis, Indiana. Paper presented at the 7th Meeting of NASA-ASD Refractory Composites Working Group, Lockheed Missiles & Space Company, Palo Alto, California. March 12-14, 1963
(7 pages, 3 figures)

The short-time high-temperature reactions investigated during the past 9 months include the binary systems HfN-C and Ta-C and the ternary system W-HfN-C, in the temperature range 4700 to 5700 F. The carbon was present in the ternary system both as solid phase and as carbonaceous gases from ablating nylon. It was concluded that HfN is an effective reaction barrier in preventing tungsten eutectic melting in contact with carbonaceous materials for short times, 180 seconds, up to 5400 F. Tantalum is almost as effective as a reaction barrier against carburization but its use is limited by its melting point, 5400 F.

51207 See Tungsten.

51210 REFRACTORY DEVELOPMENTS FOR SPACE APPLICATIONS. J. W. Graham, Astro Met Associates Inc., Cincinnati, Ohio. Paper prepared for the 7th Meeting of the Refractory Composites Working Group, Palo Alto, California. March, 1963
(7 pages)

In about one and one-half years since its organization, Astro Met has gone into a variety of refractory material developments for a wide range of applications. A brief description is given of some of the considerations that have gone into their development, and their general status at this time.

Ceramic Oxide

50877 ELECTRICAL CONDUCTION IN NONSTOICHIOMETRIC α-Nb_2O_5. R. F. Janninck and D. H. Whitmore, Northwestern University, Technological Institute, Evanston, Illinois. Office of Naval Research, Technical Report No. 3, March 14, 1963, Contract No. NONR 1228 (16)
(16 references, 8 pages, 3 figures, 1 table)

The electrical conductivity of nonstoichiometric α-Nb_2O_{5-x} was measured as a function of both the composition over the range $0.001 \leq x \leq 0.137$ and the temperature from 77 to 1270 K. The temperature dependence of the conductivity of a specimen of fixed oxygen content may be rationalized on the basis of excitation of electrons from donor centers at low temperatures and an exhaustion region at high temperatures. The conductivity data are interpreted in terms of an oxygen ion vacancy defect capable of trapping two electrons which can be thermally excited into a narrow 4d conduction band. Assuming this type of defect, an estimate of the mobility of the electrons in the conduction band is made from the conductivity data in the exhaustion region.

51091 NONDESTRUCTIVE ANALYSIS OF THE BRITTLE FRACTURE BEHAVIOR OF CERAMIC MATERIALS. J. H. Lauchner, T. F. Torries, and J. L. Pentecost, Mississippi State University, State College, Mississippi. ASD, ASD TR 61-436, Part 1, Technical Report, February, 1963, Contract No. AF 33(616)-7347
(62 references, 51 pages, 25 figures, 2 tables).

A literature survey of theoretical and experimental approaches to brittle fracture was directed toward a nondestructive evaluation point of view. Surface-decorating techniques were investigated.

A technique for calculating maximum stress in an elastic loop was developed and applied to the measurement of the strength of glass fibers from three to seven mils in diameter. The strength values were related to surface condition by surface decoration techniques. Surface-flaw decoration of cleaned and polished surfaces was performed by condensation of water on the surface. Minute flaws estimated to be less than 1000 Å deep were easily revealed.

Capacitance behaviors of polycrystalline materials were studied. Residual-stress effects were observed under statically loaded conditions.

51092 ULTRASONIC METHODS FOR NONDESTRUCTIVE EVALUATION OF CERAMIC COATING. K. E. Feith and W. E. Lawrie, Armour Research Foundation of Illinois Institute of Technology, Chicago, Illinois. ASD, WADD TR 61-91 Pt II, Technical Documentary Report, February, 1963, Contract No. AF 33(616)-6396
(44 pages, 24 figures)

This report describes investigations into the use of ultrasonic techniques to determine the strength and integrity of ceramic-metal bonds. An acoustic image converter system was used successfully to obtain a television-type display of 1/32-inch-diameter laminar defects in a zirconium oxide-Inconel bond. The measured defect thickness varied between 300 and 500 microinches or about a factor of three greater than the average large grain in the coating material. Schlieren

51092 (Continued)

optical and acoustic lens techniques were used to visually investigate detailed properties of ultrasonic fields and the interaction of ultrasonic energy with a solid. The theory of Rayleigh waves was reviewed to provide a framework for experimental integrity determinations of ceramic coatings.

51209 SURVEY OF CERAMIC RESEARCH PROGRAMS SPONSORED BY GOVERNMENT AGENCIES. N. L. Hecht, Picatinny Arsenal, Dover, New Jersey. Paper prepared for the 7th Meeting of the Refractory Composites Working Group, Palo Alto, California. March, 1963
(numerous pages)

This report reviews the ceramic research programs under government agencies. It is not meant to be an all-inclusive compilation of ceramic research sponsored by government agencies, but rather a broad view of the range of efforts and interests of these agencies.

Due to large numbers of research projects being sponsored in ceramics, the projects are listed under the sponsoring agency rather than work area.

REFRACTORY METALS

50863 RESEARCH IN PROTECTIVE COATINGS FOR REFRACTORY METALS. P. J. Chao, G. J. Dorner, B. S. Payne, Jr., J. B. Whitney, and J. Zupan, The Pfaudler Company, Rochester, New York. PF 63-2, March, 1963, prepared for the 7th Meeting of the Refractory Composites Working Group, Palo Alto, California. March 12-14, 1963
(10 pages, 5 figures)

This report summarizes the experimental work performed at Pfaudler since the 1962 meeting of the Refractory Composites Working Group at Dayton, Ohio. The work reported ranges from basic evaluation of electrophoretic properties of particles to scale-up and large scale application of a proven coating, PFR-6. Included in the work was a variety of coating application processes and some coating systems development.

50872 INVESTIGATION OF ULTRASONIC WELDING OF REFRACTORY METALS AND ALLOYS. Aeroprojects Inc., West Chester, Pennsylvania. Bureau of Naval Weapons, Bimonthly Progress Report No. 2, January, 1963, Contract No. NOw 63-0125-c
(2 references, 6 pages, 3 figures)

The programming of ultrasonic-welding power is shown to be straightforward. Similar control of clamping force involved employment of various hydraulic circuitry prior to achievement of acceptable response time. Use of an alternate-valve component in the hydraulic system is to be investigated for result comparison purposes. Problems relative to establishment of specifications for quality refractory metals are mentioned.

50930 DEVELOPMENT OF THE PROCESS OF FLAME MACHINING WITH CHLORINE. H. E. Pattee, R. E. Monroe, and D. C. Martin, Battelle Memorial Institute, Columbus, Ohio. ASD TDR 63-171, Final Report, March, 1963, Contract No. AF 33(657)-8615
(37 pages, 16 figures, 2 tables)

It has been possible to simulate metal-turning operations using a stream of chlorine gas directed on a metal surface which has been heated by plasma-arc procedures. Copper was used to prove the capability of this process because chlorine reacts with copper at low temperatures and the reaction rate is rapid; by adjusting the flow of chlorine and the angle at which the stream of gas struck the rotating workpiece, it was possible to remove sizeable amounts of metal and to volatilize the metal chlorides which were formed. Rotary machining was enhanced because the same area passed repeatedly through the chlorine stream and metal was gradually removed. It has not been possible to make linear cuts in sheet stock because the reaction rate is slow compared to the desired cutting speed. This process should be extended to include the machining of the refractory metals, since their reaction temperatures and rates with chlorine are comparable to those of copper.

50946 ECM CUTTING FLUIDS AND "CHEMICAL CHIP" DISPOSAL. W. B. Kleiner, Hanson-Van Winkle-Munning Company, Matawan, New Jersey. Paper No. 618D presented at the Society of Automotive Engineers Congress, Detroit, Michigan. January 14-18, 1963
(8 pages, 7 figures, 2 tables)

This paper is concerned with the choice of cutting fluid and "chemical chip" removal in electrochemical machining (ECM). In the ECM process, the chips or metal turnings are not in form of the original metal, but are dissolved in solution in chemical form and subsequently precipitate as metal hydroxides or chemical chips.

51048 HIGH TEMPERATURE MATERIALS PROGRAMS AT THE UNIVERSITY OF DAYTON RESEARCH INSTITUTE. J. C. Wurst and J. A. Cherry, University of Dayton, Research Institute, Dayton, Ohio. Paper presented at the 7th Meeting of NASA-ASD Refractory Composites Working Group, Lockheed Missiles & Space Company, Palo Alto, California. March 12-14, 1963
(10 references, 10 pages, 11 figures, 3 tables)

The current high-temperature materials evaluation effort at the University of Dayton Research Institute can be separated into two broad categories: the development of evaluation procedures for coated refractory alloys and the development of techniques for the evaluation of a variety of high-temperature materials by means of an arc-plasma-jet.

The coatings program has as its goal the development of an orderly series of tests which will provide a comprehensive evaluation of refractory-alloy coatings. The general philosophy of this program and specific details of each test are presented in Section one of this paper.

Section two treats the arc-plasma-jet-materials evaluation program. This effort has been highlighted in recent months by the conversion of all materials screening to the 100 kilowatt plasma jet; the development of a microablation test for the evaluation of reinforced plastics; and substantial progress in the development of a test apparatus for the evaluation of subscale, radiation cooled nozzles.

51075 DETERMINATION OF THE EFFECTS OF PROCESSING REFRACTORY METALS UNDER VACUUM. F. R. Cortes, The Universal-Cyclops Steel Corporation, Bridgeville, Pennsylvania. ASD, ASD-TDR-62-618, Technical Documentary Report, February, 1963, Contract No. AF 33(616)-8212
(107 pages, numerous figures, numerous tables)

Ten representative refractory metal alloys were chosen for vacuum rolling studies. The degree and/or the effect of contamination incurred on 90Ta-10W, F-48, D-31, TZM, and Mo-0.5 per cent Ti sheet hot rolled at 0.5 microns and at 100 microns pressure was evaluated over a range of rolling parameters. Data are presented showing qualitative differences in fabricability with pressure of each of these alloys. Mechanical property and metallographic data provide a quantitative indication of vacuum purity levels required to prevent surface contamination or minimize its effect in various alloys.

Two alloys - D-41 and W-0.6CB - could not be successfully processed to starting size sheet for vacuum rolling studies due to the lack of sufficiently developed sheet-processing procedures. In addition, technical difficulties prevented the vacuum rolling and evaluation of three tungsten-base materials chosen for evaluation.

51169 See High Strength Alloys.

51196 See Coatings.

51204 REFRACTORY METAL COATING SYSTEMS UTILIZED ON A TYPICAL HYPERSONIC GLIDE RE-ENTRY VEHICLE. J. D. Culp, McDonnell Aircraft Corporation, St. Louis, Missouri. Paper prepared for the 7th Meeting of the Refractory Composites Working Group, Palo Alto, California. March, 1963
(32 pages, 31 figures)

This paper briefly describes the refractory-metal-coating systems utilized on a typical hypersonic glide re-entry vehicle. The successful completion of such a project requires the integration of design, fabrication and coating processes. Since each project has its individual design peculiarities and final mission, a relatively large amount of testing must be expected. As production of a refractory-metal structure having the complexity of a glide re-entry vehicle proceeds, the infancy of the refractory-metal coating technology becomes very obvious. As a general rule, the application of refractory metal-coating technology to the aerospace field has been greatly oversimplified and a realistic understanding of the problems involved has not been demonstrated. It is believed by McDonnell Aircraft Corporation that the basic direction and philosophies of protecting refractory-metal structures will have to be modified before they can be efficiently utilized by the aerospace industry.

Columbium

50866 JOINING OF REFRACTORY METALS BY BRAZING AND DIFFUSION BONDING. W. R. Young and E. S. Jones, General Electric Company, Evendale, Ohio. ASD, ASD-TDR-63-88, Technical Documentary Report, January, 1963, Contract No. AF 33(616)-7484
(4 references, 109 pages, 48 figures, 12 tables)

Braze alloys were designed and evaluated for metallurgical compatibility with Cb-base materials, transition temperature, and high-temperature strength of brazed joints. Four braze alloys: AS-540 (60V-30Cb-10Ti), AS-541 (60V-30Cb-10Ti-.2C), AS-546 (60V-30Cb-10Zr), and AS-547 (59V-29Cb-10Zr-2Si), have been identified which exhibited excellent metallurgical compatibility and high-temperature strength. Low-temperature ductility of F-48 brazements, however, was decreased somewhat as a result of the brazing process.

The possibility of, and important variables in achieving brazed joints possessing failure temperatures above the original brazing temperatures were investigated. Braze alloys containing appreciable additions of melting-point depressing elements were generally found unsuitable due to excessive brittleness. An increase in failure temperature of 500 F, however, could be attained with more ductile and compatible braze alloys. Applied stress during testing was the most critical parameter influencing this failure temperature.

Although only relatively minor efforts were directed to the brazing of unalloyed tungsten, a braze alloy, AS-517 (Cb-2. 2B), has been identified which produced tungsten brazements of excellent strength at 2500 and 3000 F without significant adverse effect on low-temperature ductility.

The characteristics of diffusion-bonding refractory alloys to grossly dissimilar materials have been investigated by metallographic examination, post-bonding thermal exposure, and bonding shear strength determination. As may be expected from their unfavorable differences in atomic size, electronegativity and/or crystal structure, diffusion-bonded joints between the body-centered-cubic refractory alloys and the Fe-, Ni-, and Co-base alloys were characterized by intermetallic formation at the bonding interface. Although these joints were ductility limited at low temperatures, examples were found which exhibited sufficient plastic flow and, hence, useful strength at elevated temperatures. It has been shown that the extent of intermetallic formation may in some cases be restricted by the use of an intermetallic material as a diffusion barrier.

51051 CURRENT RESEARCH ON REFRACTORY COMPOSITES. E. L. Strauss, Martin Marietta Company, Baltimore, Maryland. February, 1963, paper presented at the 7th Meeting of NASA-ASD Refractory Composites Working Group, Lockheed Missiles & Space Company, Palo Alto, California. March 12-14, 1963
(8 references, 19 pages, 12 figures)

This report gives a brief description of three research programs dealing with refractory composites which are currently conducted at the Martin Company Space Systems Division. They are: (1) brazed refractory metal honeycomb sandwich panels, (2) resin-impregnated porous ceramics, and (3) ablative ceramic composite structures.

51086 See Tantalum.

51089 See Vanadium.

51200 RECENT DEVELOPMENTS AT MARTIN-DENVER IN THE REFRACTORY COMPOSITES AREA. The Martin Company, Denver, Colorado. February, 1963, paper presented at the 7th Meeting of the Refractory Composites Working Group, Palo Alto, California. March, 1963
(1 reference, 12 pages, 6 figures, 3 tables)

Coated D-14 columbium alloy is subject to cracking under cycling in oxidizing atmospheres at 2500 F. Martin-Denver and the Pfaudler Company of Rochester, New York investigated this problem using a heat-shield panel with the first Pfaudler coating cycle. Results are given.

51202 See Molybdenum.

51206 See Composites.

Molybdenum

51050 See Tungsten.

51051 See Columbium.

51131 REFRACTORY METALS IN AIRFRAME DESIGN. R. H. Hepper, McDonnell Aircraft Company, St. Louis, Missouri. March 29, 1963, paper presented at the 1963 ASM Western Metal Congress
(3 pages, 7 figures)

Refractory metals are extremely expensive, difficult to fabricate, and require protective coatings against oxidation. Is it justifiable to use such troublesome materials? The purpose of this paper is to explore this question, and to discuss some of the fabrication problems of refractory metals and their solutions. The author discusses the problem of lamination in molybdenum sheet and describes the "chem blanking" process used at McDonnell to avoid delamination in sawing or shearing operations.

51149 EVALUATION OF ELECTRON BEAM WELDING OF ALLOYED MOLYBDENUM SHEET. A. S. Rabensteine, The Marquardt Corporation, Van Nuys, California. PR 281-1Q-3, September 12, 1962, AD 284 456, Contract No. AF 33(657)-8706
(9 references, 28 pages, 13 figures, 5 tables)

An investigation was conducted to evaluate the electron-beam welding process as applied to the joining of alloyed molybdenum sheet. Both low-voltage and high-voltage welding equipment were utilized in the study. This enabled comparison of results to see if either type of equipment had distinct advantages.

Welded test panels were evaluated radiographically, metallographically and mechanically. The tensile properties at temperatures up to 3200 F were obtained for both the welded specimens and parent material.

51202 EMITTANCE MEASUREMENTS OF DISILICIDE - TYPE COATINGS AT THE U. S. NAVAL RADIOLOGICAL DEFENSE LABORATORY. N. J. Alvares, United States Naval Radiological Defense Laboratory, Washington, D. C. Paper prepared for the 7th Meeting of the Refractory Composites Working Group, Palo Alto, California. March, 1963
(5 pages, 5 figures)

The total hemispherical emittance and normal spectral emittance of oxidation-resistant coatings were measured on molybdenum, tungsten, niobium, and tantalum at the United States Naval Radiological Defense Laboratory (NRDL). Coatings were studied through the useful temperature range in air.

Results are given for PRF-6, Durak B, and C.V. 1V (Mo) coatings on molybdenum.

Tantalum

51086 ANELASTIC BEHAVIOR OF TANTALUM AND COLUMBIUM. R. J. Sneed, E. L. Fink, and M. C. Abrams, General Dynamics/Pomona, Pomona, California. ASD, ASD-TDR-62-323, Technical Documentary Report, February, 1963, Contract No. AF 33(616)-7235
(49 references, 121 pages, 18 figures)

A theoretical model is developed based on dislocation-interstitial interaction during stress application, which describes the anelastic behavior of body-centered cubic metals particularly during yield delay. It is shown that the reorientation of interstitial impurities apparently controls both the preyield microstrain rate and the time to yield. The model is supported for tantalum and columbium by the results of yield-delay experiments over a temperature range from -97 F to 400 F. Activation energies of the yield-delay process calculated both from microstrain-rate data and time-to-yield information indicate that hydrogen diffusion has a controlling effect, with other interstitials contributing to the effective activation energies at the higher temperatures. Temperature-insensitive stress effects are noted.

The model is further substantiated by X-ray diffractometry which demonstrates the occurrence of anelastic lattice strains during load application and their consequent recovery.

A brief resume is given on the initial efforts of a high-temperature study on the anelasticity in tantalum and columbium. This study is aimed at exploring anelastic behavior up to 3000 F.

51195 See Tungsten.

51202 See Molybdenum.

51206 See Composites.

Vanadium

50868 CHEMICAL AND GALVANIC CORROSION PROPERTIES OF HIGH-PURITY VANADIUM. C. B. Kenahan, D. Schlain, and W. L. Acherman, United States Department of the Interior, Bureau of Mines, Washington, D. C. RI 5990, 1962 (22 pages, 10 figures, 9 tables)

Vanadium is subject to only light corrosion in phosphoric acid at temperatures up to 60 C and has a moderate corrosion rate in this acid at 100 C. It is relatively corrosion resistant in sulfuric and hydrochloric acids up to 60 C but corrodes rapidly at 100 C. It corrodes rapidly in dilute nitric acid at 35 C. Vanadium is almost inert in 10 per cent solutions of formic, acetic, lactic, tartaric, and citric acids; in 9 per cent oxalic acid it corrodes slowly up to 60 C and rapidly at 100 C. Vanadium is resistant to corrosion in substitute ocean water, tapwater, and in 3 per cent sodium-chloride and 10 per cent sodium-hydroxide solutions. It is readily attacked, however, by 20 per cent ferric-chloride, 20 per cent cupric-chloride and 5 per cent mercuric-chloride solutions.

Vanadium is protected by contact with magnesium, aluminum, and steel SAE 4130 in substitute ocean water, by magnesium and aluminum in 3 per cent sodium-chloride solution, and by magnesium in tapwater. Vanadium protects copper in substitute ocean water. When vanadium and stainless steel are coupled in sulfuric-acid solutions, both metals are usually unaffected by contact, whereas the corrosion rate of titanium in sulfuric acid is greatly reduced by contact with vanadium.

51089 HIGH-TEMPERATURE OXIDATION PROTECTIVE COATINGS FOR VANADIUM-BASE ALLOYS. J. J. Rausch and F. C. Holtz, Armour Research Foundation of Illinois Institute of Technology, Chicago, Illinois. Bureau of Naval Weapons, Bimonthly Report No. 3, April 8, 1963, Contract No. N600(19)59182 (17 pages, 2 figures, 3 tables)

Basic pack-siliconizing-processing variables such as time, temperature, edge and surface preparation, activator concentration, and powder size are being investigated to optimize oxidation life and coating adherence for thin sheet material.

Fifteen vanadium-columbium alloy compositions have been pack siliconized and oxidation tested. Minimum life has been established at about 150 hours at 2200 F for each of the alloys.

Tungsten

50866 See Columbium.

50962 THE INVESTIGATION OF THE ACTIVATED SINTERING OF TUNGSTEN POWDER. J. H. Brophy, H. W. Hayden, A. L. Prill, and J. Wulff, Massachusetts Institute of Technology, Cambridge, Massachusetts. Bureau of Naval Weapons, Final Report, February 28, 1963, Contract No. NOw 61-0326-d (16 references, 108 pages, 16 figures, 5 tables)

Low temperature densification of tungsten can be accelerated by additions of palladium, rhodium, ruthenium, and platinum in a manner similar to that observed with nickel additions. The cause for this acceleration is an enhancement of the grain-boundary diffusion process found to dominate the densification of commercially pure tungsten in the same temperature range. In contrast to the other Group VIII elements examined, iridium retards the densification of tungsten at 1100 C. An analysis of activated solid state sintering and more conventional liquid-phase sintering in tungsten indicates that the two processes are similar and together comprise a general phenomenon called carrier-phase sintering.

50968 EFFECT OF OXYGEN ON MECHANICAL PROPERTIES OF TUNGSTEN. J. R. Stephens, Lewis Research Center, Cleveland, Ohio. NASA TN D-1581, Technical Note, April, 1963
(15 references, 23 pages, 11 figures, 3 tables)

Additions of oxygen to polycrystalline tungsten increased the ductile-to-brittle transition temperature, whereas oxygen additions to single-crystal tungsten produced only a slight increase in the transition temperature. The yield and ultimate tensile strengths of polycrystalline material were reduced, whereas the strength properties of the single-crystal material were unchanged as a result of oxygen additions. Effects of oxygen as a surface oxide were evaluated. Heating tungsten in oxygen at 1000 F did not affect the ductility of tungsten; but a 1500 F ductility could be enhanced if the oxidation were allowed to continue for a sufficient period of time to smooth the roughened surface layer.

51050 REPORT TO REFRACTORY COMPOSITES WORKING GROUP. Western Gear Corporation, Lynwood, California. Paper presented at the 7th Meeting of NASA-ASD Refractory Composites Working Group, Lockheed Missiles & Space Company, Palo Alto, California. March 12-14, 1963
(4 pages, 12 tables, 2 figures)

During the past year, Western Gear Corporation's Research Laboratory has concentrated in-house development efforts in the plasma-material-deposition field on: (1) the development of techniques for fabricating complex free standing shapes, (2) the mechanical properties of sprayed materials, and (3) optimizing the plasma process for beryllium fabrications.

Curves are presented which show the results of various tests conducted on tungsten, molybdenum, and beryllium free-standing shapes.

51058 NEW TECHNIQUE FOR PLASMA SPRAYING TUNGSTEN. F. N. Longo, Metco, Inc., Westbury, Long Island, New York. Paper presented at the 7th Annual Meeting of NASA-ASD Refractory Composite Working Group, Lockheed Missiles & Space Company, Palo Alto, California. March 12-14, 1963
(3 pages, 4 figures)

Preliminary work has been under-way for developing a new technique for plasma-flame-spraying tungsten without special inert conditions, for producing coatings or shapes which are more dense and have higher tensile strengths than those ordinarily sprayed in open atmosphere. The method utilizes special cooling jets of carbon dioxide.

The use of the CO_2 cooling allows spraying at higher temperature without inert cover, while preventing the workpiece from overheating and oxidizing.

51079 TUNGSTEN SHEET ROLLING PROGRAM. G. C. Bodine, Jr., Fansteel Metallurgical Corporation, North Chicago, Illinois. Bureau of Naval Weapons, Final Report, March 1, 1963, Contract No. NOw-60-0621-c
(85 pages, 19 figures, 34 tables)

Powder metallurgy tungsten plate and sheet has been produced in quantity according to optimum processing procedures developed in the pilot powder and sheet phases. Inspection and test results show the material to be of good quality but not as consistent as full scale pilot material. Part of the inconsistency results from deviations in original dimensional targets and the resulting processing changes; and part is the result of the diminishing degree of process control which invariably occurs during the transition from pilot to production runs. The use of high-quality starting materials will not insure high-quality end product unless processing equipment and personnel are compatible with the degree of control necessary for the quality level desired. Examination of all program data indicates that extremely close controls are an absolute prerequisite for the production of consistent and reliable powder-metallurgy tungsten plate and sheet. The Bureau of Naval Weapons Tungsten Sheet Rolling Program has made a significant contribution to industry through the determination of the material and process parameters which will be necessary to provide a tungsten flat rolled product worthy of the calssification of "aerospace quality". This final report contains a condensation of all significant information contained in previous interim reports, subsequent work, a complete description of the finished articles, and recommendations based upon the work conducted in the program.

51195 HIGH TEMPERATURE PROTECTIVE COATINGS FOR REFRACTORY METALS - PART I & II. L. Sama and C. D. Dickinson, General Telephone and Electronics Laboratories Inc., Bayside, New York. TR 63-475.4, paper prepared for the 7th Meeting of the Refractory Composites Working Group, Palo Alto, California. March 12-14, 1963
(7 references, 48 pages, 16 figures, 2 tables)

The coating work being conducted at this laboratory consists of two parts: Part I is concerned with the practical development of coatings for all of the refractory metals and Part II is a more fundamental program which is directed toward clarification of factors of importance in

51195 (Continued)

coatings for tungsten above 1900 C. The objective of this portion of the report is to summarize the work in progress in Part I which covers a fairly broad spectrum of the refractory metals and alloys and, particularly, to give some of the highlights of results obtained on an Air Force-sponsored program on several tantalum-base alloys.

51202 See Molybdenum.

51205 OBSERVATIONS ON METALLURGICAL BONDING BETWEEN PLASMA SPRAYED TUNGSTEN AND HOT TUNGSTEN SUBSTRATES. S. J. Grisaffe and W. A. Spitzig, National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio. Paper prepared for 7th Meeting of the Refractory Composites Working Group, Palo Alto, California. March 12-14, 1963
(2 references, 8 pages, 9 figures)

While considerable work has been carried out on plasma-sprayed coatings, very little effort has been directed toward a critical examination of the resultant particle-to-substrate bonds. Since the characteristics of the initial bond generally determine the adherence and strength of bonding of any applied coating, improved bonding from one of mechanical interlock to one that is truly metallurgical is important. Therefore, an investigation was undertaken to explore the type and quality of coating-to-substrate bonds which can be obtained during plasma spraying. This work is a portion of a larger effort to characterize more fully the plasma-spray-deposition phenomenon and to develop improved plasma-spray coatings.

51207 PLASMA-SPRAYED OXIDE AND VAPOR-DEPOSITED NITRIDE COATINGS ON TUNGSTEN AS A MEANS OF ACHIEVING OXIDATION PROTECTION. J. L. Bliton and J. J. Rausch, Armour Research Foundation of Illinois Institute of Technology, Chicago, Illinois. Paper prepared for the 7th Meeting of the Refractory Composites Working Group, Palo Alto, California. March 12-14, 1963
(5 pages, 2 tables)

This paper describes current studies in which attempts are being made to utilize refractory oxide and nitride coatings as a means of protecting tungsten from oxidation. This work is part of a program directed to developing effective coating systems for refractory metals at temperatures above 3600 F for use in low-pressure, liquid-fueled, rocket engines. Oxide coatings were applied by plasma spraying, and the nitride coatings by chemical-vapor deposition. Methods of improving adherence, coating density, uniformity, and thermal shock resistance are being investigated, and protective capability is being evaluated.

51211 ARC PLASMA SPRAYED TUNGSTEN AS AN ENGINEERING MATERIAL. A. Eisenlohr, Arde-Portland, Inc., Paramus, New Jersey. Paper prepared for the 7th Meeting of the Refractory Composites Working Group, Palo Alto, California. March, 1963
(7 pages)

51211 (Continued)

One of the most attractive fabrication methods for producing complex missile composites is the arc-plasma-spraying process. Tungsten-lined bodies, fabricated by this method have had densities as low as 80 per cent of the theoretical density of tungsten. Consequently, these bodies or coatings lacked the properties required in both free-standing components and in erosion-resistant coatings applied to substrates. In addition, tungsten deposited under open-air conditions has resulted in excessively large amounts of oxide content, which adversely affect the physical properties of the deposit.

Investigations were undertaken first, to produce high-density, high-purity, and high-strength tungsten deposits which could function in the "as-sprayed" condition. A second phase of effort was undertaken to determine the effects of subsequent thermal treatments on the properties of the sprayed tungsten. These thermal treatments included vacuum sintering and isostatic gas compaction.

51225 INVESTIGATION OF VARIATIONS IN RAW MATERIALS AND PRODUCTION PROCESSING ON THE PROPERTIES OF TUNGSTEN METAL SHEET. Clyde Williams Corporation, London, England. Navy, Bureau of Aeronautics, Interim Report No. 3, February, 1963, Contract No. Noas N62558-3235
(. pages, 2 figures)

The reduction of tungsten trioxide by different metals has been investigated. Pyrophorous extremely fine particle tungsten powder has been obtained by zinc reduction at low temperature. Reduction using magnesium yields a tungsten powder of very good quality. There are, however, considerable difficulties to overcome while using sodium or calcium as reducing agents because of the formation of protecting layers. The experiments for tungsten-powder preparation by electrolysis have been continued resulting in products containing α- and β - tungsten.

The particle size observed microscopically was 0,5μ and smaller with all powders, while the primary crystallite size determined from X-ray-diffraction-line broadening is 250 Å in pyrophorous powders. The experiments with the photo-sedimentometer have been continued.

MISCELLANEOUS

50880 PROCEEDINGS OF THE 18TH ANNUAL TECHNICAL & MANAGEMENT CONFERENCE REINFORCED PLASTICS DIVISION. Society of the Plastics Industry, Inc., New York, New York. 18th Annual Meeting, Chicago, Illinois. February 5-7, 1963
(numerous references, numerous pages, numerous figures, numerous tables)

A total of eighty-one papers were presented at this 18th Annual Meeting of the Society of the Plastics Industry, Inc. Among the many subject areas covered are the following: applications of filament winding, retention of virgin fiberglass properties, effect of specimen preparation on mechanical test properties, stress analysis of filament-wound pressure vessels, design considerations of filament-wound structures, mechanics of failure of filament-wound vessels, tape wrapping of thermal insulation, and sandwich construction.

50907 SOME METALLURGICAL AND SOLID STATE RESEARCH IN STOCKHOLM. D. S. Lieberman, Office of Naval Research, London, England. ONRL-2-63, Technical Report, January 30, 1963
(22 pages, 7 figures, 1 table)

This report contains observations made on some of the metallurgical and solid-state physics research programs in several institutions in Stockholm: the Swedish Institute for Metal Research, The Royal Institute of Technology (KTH), and the University of Stockholm.

50966 See Applications.

50974 TITAN II STORABLE PROPELLANT HANDBOOK - FINAL HANDBOOK - REVISION B. R. R. Liberto, Bell Aerospace Corporation, Bell Aerosystems Company, Buffalo, New York. AFBSD TR 62-2, Report No. 8182-933004, March, 1963, Contract No. AF 04(694)-72
(80 references, numerous pages, numerous figures, numerous tables)

Summarized are the physical properties, materials compatibility, handling techniques, flammability and explosivity hazards, and procedures for storing, cleaning, and flushing of the Titan II propellants, N_2O_4 as the oxidizer and a nominal 50/50 blend of UDMH and N_2H_4 as the fuel. The data presented was derived both from a literature survey and from a test program conducted at Bell Aerosystems Company and at the U. S. Bureau of Mines.

51049 HYPERTHERMAL RESEARCH FACILITY - PROGRESS REPORT NO. 3. R. A. Stevens and J. E. Burroughs, General Dynamics, Fort Worth, Texas. Paper presented at the 7th Meeting of NASA-ASD Refractory Composites Working Group, Lockheed Missiles & Space Company, Palo Alto, California. March 10-14, 1963
(2 references, 7 pages, 3 figures, 1 table)

The 1.8 megawatt arc-heated Hyperthermal Research Facility (HRF) is currently in operation at General Dynamics/Fort Worth. Basically

51049 (Continued)

this facility is a high enthalpy (18,000 British thermal units per pound) free jet, supersonic/hypersonic wind tunnel which uses gases such as air, nitrogen, argon, etc., as the primary working fluid.

The primary function of the HRF is ablation testing and the simulation of re-entry thermal environments. The estimated range of enthalpy which can be achieved with the HRF arc heater is shown. Experimental data obtained to date are also shown.

51051 See Columbium.

51054 CONTAINER FAILURE DETECTION SYSTEM. A. B. Wieczorek and M. B. Levine, General American Transportation Corporation, Niles, Illinois. ASD, ASD TR-915 (IV), Interim Technical Engineering Report, Contract No. AF 33(657)-7461
(56 pages, 24 figures)

A prototype system has been fabricated and tested with a model billet container. Records produced by the system during the tests indicate a high degree of capability and reliability in detecting longitudinally-oriented cracks.

The pulse-echo technique was adopted; though preliminary experiments with through transmission promised sufficient sensitivity for automated recording of flaw depth and location, further investigation utilizing the model billet container revealed effects detrimental to its successful use. Integration of the "roller skate" water coupler, scanning system and recording system was accomplished through tests conducted with the model billet container. Subsequent inspection with the system has revealed its ability to detect naturally-occurring longitudinally-oriented cracks.

51055 ELASTO-PLASTIC ANALYSIS OF STRUCTURES UNDER LOAD AND TWO-DIMENSIONAL TEMPERATURE DISTRIBUTIONS. R. J. Edwards, Martin Marietta Corporation, Baltimore, Maryland. ASD, ASD-TR-61-667 Vol III, March, 1963, Contract No. AF 33(616)-7738
(6 references, 93 pages, 45 figures, 3 tables)

This report describes investigations performed to determine experimentally the validity of the time-dependent aspects of a time-dependent elasto-plastic stress-and-strain-analysis method (published in ASD TR-61-667 Vol. I "Elasto-Plastic Analysis of Structure Under Load and Two-Dimensional Temperature Distributions") for structures exposed to complex load and two-dimensional elevated-temperature environments. An experiment specifically designed to evaluate the accuracy of the theoretical method is presented. This consisted of a test of a long flat plate subjected to step functions of load randomly combined with several two-dimensional temperature distributions. Magnitude and duration of the test variables were such that plasticity, creep, and appreciable thermal-stress systems were introduced. Comparisons are made of experimental total strains with analytical total strains calculated for conditions identical with the test. The degree of correlation achieved indicates verification of the analysis method within the range of test parameters selected.

51057 See Composites.

51066 REFRACTORY METALS STRUCTURAL DEVELOPMENT PROGRAM VOLUME V: STRUCTURAL COMPONENT TEST. C. W. Neff, K. L. Denny and R. G. Frank, McDonnell Aircraft Corporation, St. Louis, Missouri. General Electric Company, Evendale, Ohio. ASD TR 61-392, Volume V, Final Report, February, 1963, Contract No. AF 33(616)-6578
(1 reference, 333 pages, 614 figures, 8 tables)

The purpose of this program was to design, fabricate, and test a representative load-carrying structural component capable of efficient operation in the temperature range of 1800 F to 2500 F. The component was designed to be temperature resistant and entirely self-sustaining in the above mentioned temperature range with no auxiliary insulating or cooling devices.

This report presents the test results of the structural component (Fin and Rudder) testing and is one of a series of five volumes which when combined with the other four volumes constitute the final technical report of this contract.

51074 DEVELOPMENT OF A MATERIALS PROPERTY DATA PROCESSING SYSTEM. R. C. Braden and C. S. Wright, Belfour Engineering Company, Technical Information Systems Division, Suttons Bay, Michigan. ASD, ASD-TDR-63-128, Technical Documentary Report, January, 1963, Contract No. AF 33(616)-7238
(70 pages, 2 figures, 6 tables)

This report discusses a mechanical properties information system including the operation of a fatigue of metals subsystem and the design-development and initial operation of other mechanical properties subsystems. These subsystems, employing punched card equipment and techniques, actively provide mechanical properties data and associated descriptive information of metals and reinforced plastics.

The system, sponsored by the USAF, is intended primarily for the use of Defense Agencies and their contractors.

Formats, codes and procedures utilized to store, retrieve and display mechanical properties of these materials are outlined.

This technical documentary report has been reviewed and is approved.

51083 DEVELOPMENT OF 2400°F FORGING DIE SYSTEM. N. Nudelman, T. Watmough, and P. R. Gouwens, Armour Research Foundation of Illinois Institute of Technology, Chicago, Illinois. ASD, ASD TR 7-886 (VIII), Interim Technical Progress Report, April, 1963, Contract No. AF 33(600)-42861
(11 pages, 1 figure, 2 tables)

The prototype die has been assembled and heating experiments initiated. These indicated that with Calrod heating a die face temperature of 1300 F can be obtained. This will be supplemented by gas-flame radiation heating on the die face to attain a temperature of 2400 F. Experiments utilizing calcium-flouride-sodium-fluoride salt combinations to give oxidation protection to the refractory-metal-die components were successfully performed. A spectrum of viscosities can be obtained with this salt combination by relatively minor adjustments in proportion of either of the components.

51109 METEOROID PROTECTION SYSTEM FOR SPACE VEHICLES. S. J. Pipitone and B. W. Reynolds, Goodyear Aircraft Corporation, Akron, Ohio. No. 2895-63, paper presented at the AIAA Launch & Space Vehicle Shell Structures Conference, Palm Springs, California. April 1-3, 1963
(7 references, 15 pages, 14 figures, 2 tables)

Several meteoroid protection systems have been analyzed and tested for use in rigid or foldable space or lunar structures. This paper deals with double-wall systems in which a thin outer wall and a foam spacer are attached to an inner structural wall. The foam spacer serves as a mechanical atmosphere, tending to absorb and arrest impacting materials. Test results are presented, and hypotheses explaining phenomena encountered are suggested.

51110 See Applications.

51111 See Applications.

51112 PRELIMINARY DESIGN OF STRUCTURE SUBJECTED TO SONIC FATIGUE. C. A. Rodenberger, A and M College of Texas, College Station, Texas. No. 2896-63, paper presented at the AIAA Launch and Space Vehicle Shell Structures Conference, Palm Springs, California. April 1-3, 1963
(6 references, 11 pages, 1 figure, 3 tables)

A simplified method is presented for determining the possibility of failure of structure caused by a sonic environment. The problem is reduced to an equivalent sinusoidal fatigue stress problem.

The equivalent fatigue stress is found by multiplying the static stress due to a one psi uniform loading by a damage factor and an amplification factor. Values of the damage factor are given for the expected life in cycles. The amplification factor is determined from the sound pressure level and the structural damping. Approximate values of the damping are presented.

Possibility of failure can then be determined by the application of fatigue theories.

51113 METALLURGICAL ASPECTS OF PRESSURE VESSEL FAILURES. H. Southworth, The Boeing Company, Seattle, Washington. No. 2897-63, paper presented at the AIAA Launch and Space Vehicle Shell Structures Conference, Palm Springs, California. April 1-3, 1963
(7 references, 10 pages, 8 figures)

Metallurgical factors can significantly affect pressure vessel performance. At the strength levels of current interest, material properties may be highly sensitive to variations in composition, manufacturing methods or service exposure. Most metallurgical aspects associated with failure arise from interaction with environments and microstructural effects. These are shown to influence one or more of the three progressive stages of fracture: crack initiation, slow growth, and unstable propagation. Examples are presented to illustrate both harmful and beneficial results.

51114 RECENT RESEARCH IN BUCKLING OF CYLINDRICAL SHELLS. J. P. Peterson and M. Stein, National Aeronautics and Space Administration, Langley Field, Virginia. No. 2903-63, paper presented at the AIAA Launch and Space Vehicle Shell Structures Conference, Palm Springs, California. April 1-3, 1963
(13 references, 13 pages, 12 figures)

Results from five separate research investigations by the NASA on the buckling and collapse of cylindrical shells of interest as structural components of missiles and launch vehicles are summarized. Two of the investigations provide a better understanding of the phenomena of buckling of cylinders in compression and of the collapse of pressurized cylinders in bending. In the remaining three studies, test data, which have been correlated with classical buckling theory, are given for ring-and-stringer stiffened cylinders in bending, filament-wound glass-epoxy cylinders in compression and ring-stiffened cylinders subjected to rapid heating.

51115 COST AND PERFORMANCE CONSIDERATIONS IN THE SELECTION OF STRUCTURAL MATERIALS FOR ULTRA-LARGE-SIZE BOOSTER MOTORS. R. V. Alexander and C. A. Fournier, Aerojet-General Corporation, Sacramento, California. No. 2909-63, paper presented at the AIAA Launch and Space Vehicle Shell Structures Conference, Palm Springs, California. April 1-3, 1963
(17 pages, 20 figures, 6 tables)

By use of an IBM 7090 digital computer program, preliminary design requirements were established for the fabrication of a unitized, 260-inch-diameter, solid-rocket motor to propel a payload of one million pounds to a terminal velocity of 6500 fps. Performance and relative costs were determined for motors constructed of a variety of structural steels. Two primary fabrication methods were considered. Structural materials and chamber pressures were evaluated to arrive at minimum-cost and minimum-weight vehicles for the required mission.

51116 See Applications.

51117 See Applications.

51118 See Applications.

51123 THERMAL CONSIDERATIONS LIMITING THE MECHANICAL STRENGTH OF SOLIDS. I. J. Gruntfest, General Electric Company, Philadelphia, Pennsylvania. No. 2925-63, paper presented at the AIAA Launch and Space Vehicle Shell Structures Conference, Palm Springs, California. April 1-3, 1963
(12 references, 11 pages, 6 figures)

Exploratory analytical and experimental studies show that the thermal effects which inevitably occur in mechanical experiments can be important considerations in the deformation and fracture of solids. The computations in this report indicate how the ultimate strength must be limited by thermal feedback. Time and size effects in the mechanical behavior of solids are introduced in a novel and natural manner. In addition, the distinctions between ductile and brittle behavior are illuminated to some extent.

51203 See Nonmetallics.

51226 EVALUATION OF CO-REDUCED DEPLETED URANIUM ALLOY. E. N. Kinas and F. J. Rizzitano, Watertown Arsenal Laboratories, Watertown, Massachusetts. WAL TR 420.5/1, March, 1963
(10 pages, 4 figures, 4 tables)

As study was conducted to determine the advantage of forging depleted-uranium components directly from co-reduced dingot stock. Two types of alloys were investigated: U-8 per cent Mo and U-8 per cent Mo-1 per cent Ti. To provide a basis of comparison, some of the co-reduced dingot stock was remelted into ingots and was hot worked in the same manner as the material from the dingot. Mechanical properties were obtained to determine the effect of both methods. Photomicrographs and photomacrographs were obtained to compare the effect of different processing methods and heat treatments on metallurgical structure.

The hot-working methods used were upset forging and cogging.

Data obtained from this investigation indicated that co-reduced material could be forged and heat treated directly to give good combinations of mechanical properties. Remelting of co-reduced hot-working material followed by hot working resulted in only slightly higher yield strength.

Coatings

50864 See Refractory Metals.

51194 IMPROVED PROCESSING TECHNIQUES PROVIDE APPLICATION VERSATILITY FOR VOUGHT'S HIGH TEMPERATURE OXIDATION RESISTANT COATING SYSTEMS. W. L. Aves, Jr., Chance Vought Corporation, Dallas, Texas. Paper to be presented at the 7th Meeting of the High Temperature Inorganic Composites Working Group, Palo Alto, California. March 11-14, 1963 (19 pages, 17 figures)

A brief outline of the current application techniques employed by Vought Aeronautics to improve coating continuity, applicability, and system reliability is provided. Processing techniques designated "slip-pack," and "segregated-pack" are described. The application of tailored high temperature oxidation-resistant coating systems to refractory-metal substrates by use of pyrophoric or thermit heat sources is presented for discussion.

The processing techniques and coating systems described in this paper, improved modifications of which are currently under evaluation, were conceived to provide Vought with a capability for coating large and/or highly-configurated components or fabrications (i.e., cross-flow heat exchangers, weldments, convergent-divergent nuclear ram-jet nozzles, inside diameter and outside diameter of configurated lengths of instrumentation tubing, buckets, heat shields, large leading-edge panels, etc.). The systems revealed are versatile and highly adaptable to scale-up use.

51196 HIGH TEMPERATURE OXIDATION RESISTANT COATINGS. J. C. Withers, General Technologies Corporation, Alexandria, Virginia. Paper prepared for the 7th Meeting of the Refractory Composites Working Group, Palo Alto, California. March 12-14, 1963
(8 pages, 1 figure)

The General Technologies Corporation has investigated a variety of high temperature, oxidation resistant coatings. Both methods of deposition and coating compositions have been studied. In addition, the concept of oxidation resistant coatings with a diffusion barrier has been investigated.

51197 ACTIVITY REPORT OF HIGH TEMPERATURE COATING AND MATERIAL PROGRAMS AT AMF, M. E. Browning and E. A. Schatz, American Machine and Foundry Company, Alexandria, Virginia. AMF AR 63-502, prepared for the 7th Meeting of the Refractory Composites Working Group Meeting, Palo Alto, California, March 11-14, 1963
(4 references, 26 pages, 24 figures, 1 table)

This report reviews current and recently completed AMF programs in three areas of interest: (1) high-temperature oxidation-resistant coatings, (2) composite materials, (3) thermal radiation properties.

51197 (Continued)

Individial programs are not delineated but rather discussed under the over-all activity heading. Some programs reflect work in one or more areas and, therefore, data may be counter-referenced.

51198 A PORTFOLIO OF EXPERIENCE IN REFRACTORY METAL PROTECTIVE SYSTEMS. D. H. Leeds, Aerospace Corporation, El Segundo, California. Prepared for the 7th High Temperature Composites Working Group Meeting NASA/ASD, Palo Alto, California. March 11-14, 1963
(377 pages)

The purpose of the present document is twofold: to direct research in the field of refractory metals protective coatings away from present silicide approaches and into systems capable of protection over 3500 F, and to familiarize the materials engineer with past and current research in his field (including the valuable examples set by silicide-protection theory), thereby enabling him to interpret his own science for the designer. The report is divided into five major sections: molybdenum (366 references); columbium (299 references); tungsten (497 references); tantalum (229 references); and a new section, general (201 references), which contains references to oxidation testing of refractory metal systems and to areas of research allied to the one vital problem, the protection of these metals from unfavorable environments at elevated temperatures.

51199 ACTIVITIES OF BELL AEROSYSTEMS COMPANY WITH REFRACTORY MATERIALS. F. M. Anthony, Bell Aerospace Corporation, Bell Aerosystems, Buffalo, New York. Paper prepared for the 7th Meeting of the Refractory Composites Working Group, Palo Alto, California. March, 1963
(17 pages, 4 figures, 2 tables)

Investigation of the suitability of presently available foil-gage-coated metals for heat-shield applications. Results of tests on coated columbium- and molybdenum-alloy panels and additional tests of riveted joints are reported herein along with an outline of a recently initiated program to investigate coatings for superalloy foil-gage components.

51205 See Tungsten.

51208 COATING ACTIVITIES AT TEXAS INSTRUMENTS INCORPORATED. P. F. Woerner, Texas Instruments Incorporated, Dallas, Texas. Paper prepared for the 7th Meeting of the Refractory Composites Working Group, Palo Alto, California. March, 1963
(2 pages)

Corporate sponsored programs on coatings at Texas Instruments, which are being carried out mainly in the Materials Research and Development Laboratory, are primarily concerned with vapor plating. Our primary interests are (1) to understand the basic principles and technology for these processes and (2) to utilize this technology as a tool to achieve high-temperature oxidation-resistant coatings.

50880 See Miscellaneous.

50922 FEASIBILITY OF OPTIMIZING NOZZLE PERFORMANCE FOR ORBITAL-LAUNCH NUCLEAR ROCKETS. J. R. Jack, Lewis Research Center, Cleveland, Ohio. NASA TN D-1578, Technical Note, April, 1963
(7 references, 25 pages, 8 figures)

Nozzle performance for orbital-launch nuclear rockets was evaluated for a range of operating conditions and nozzle geometries. From this study, conclusions were drawn concerning (1) optimum values of nozzle area ratio and operating pressure, (2) operating conditions for favorable nozzle heat transfer, and (3) the effects of deviations from optimum conditions.

50964 DEVELOPMENT OF IMPROVED CUTTING TOOL MATERIALS. F. C. Holtz, Armour Research Foundation of the Illinois Institute of Technology, Chicago, Illinois. ASD TDR 7-714(I), Interim Technical Documentary Progress Report, January, 1963, Contract No. AF 33(657)-8786
(27 pages, 6 figures, 5 tables)

A program concerned with the development of cutting tool materials capable of greatly increased performance in machining high-strength and refractory alloys is described. The basic requirements and the major approaches under study for improved tool materials are discussed. Experimental work performed includes the casting and forging of vanadium-enriched high-speed steel for surface carburization, the casting of highly modified high-speed steels using special foundry techniques, the atomization of carbon-enriched alloy powders for consolidation into cutting tool materials, and the hot pressing and sintering of carbide composites having high-melting matrix phases or spheroidized hard particles.

Carburized high-speed steel enriched in vanadium was found to be heat-treatable in compositions containing at least 4.6 weight per cent; alloys containing up to 18.6 weight per cent vanadium were fabricable. A high-speed steel alloy, type M1, cast into an oscillating crucible, showed a more uniform and finer structure than did a conventionally cast heat. Atomization of an M2 high-speed steel produced particles which contained extremely fine grain-boundary carbides when heated to 1205 or 1260 C for 5 minutes followed by rapid cooling to near room temperature. Initial studies of liquid-phase sintered-carbide composites showed that compositions rich in vanadium carbide exhibit high compressive strength, especially in the finer-grained alloys.

50966 CALCULATION OF TURBULENT BOUNDARY-LAYER GROWTH AND HEAT TRANSFER IN AXI-SYMMETRIC NOZZLES. D. G. Elliott, D. R. Bartz, and S. Silver, California Institute of Technology, Pasadena, California. NASA, Technical Report No. 32-387, February 15, 1963, Contract No. NAS 7-100
(30 references, 39 pages, 17 figures, 2 tables)

The method of Bartz (1954) for computing boundary-layer thicknesses, skin-friction, and heat flux in axi-symmetric nozzles has been revised and programmed for digital-computer solution. The method solves, simultaneously, the integral momentum and energy equations for thin

50966 (Continued)

axisymmetric boundary layers. Boundary-layer shape parameters are approximated from one-seventh power profiles of velocity and stagnation temperature, and skin-friction coefficient and Stanton number are evaluated as functions of boundary-layer thickness from the best available semi-empirical relations. An IBM 7090 program of the method is available.

51009 See Engineering Steels.

51049 See Miscellaneous.

51051 See Columbium.

51057 See Composites.

51088 See Carbon, Graphites.

51110 SECONDARY REINFORCING SYSTEMS FOR SPIRALLOY STRUCTURES. V. G. Parady, Hercules Powder Company, Rocky Hill, New Jersey. No. 2917-63, paper presented at the AIAA Launch and Space Vehicle Shell Structures Conference, Palm Springs, California. April 1-3, 1963
(4 references, 24 pages, 18 figures)

Local reinforcement of a filament-wound structure is often necessary to resist discontinuity stresses, to carry stresses around openings where filaments were cut, and to locally increase thickness.

This paper compiles most of the basic approaches to secondary reinforcement that have been published, as well as some not previously published. The discussion includes theoretical considerations, reinforcement materials, and fabrication methods. Simplified methods for sizing reinforcements are derived.

Types of reinforcement materials considered include glass cloth, prepreg tape, and filament-wound mats. Typical failures attributable to insufficient use of local reinforcement are illustrated photographically.

51111 DESIGNING FOR STIFFNESS AND BUCKLING IN FILAMENT-WOUND ROCKET CASE STRUCTURES. R. Ravenhall, Hercules Powder Company, Rocky Hill, New Jersey. No. 2904-63, paper presented at the AIAA Launch and Space Vehicle Shell Structures Conference, Palm Springs, California. April 1-3, 1963
(12 references, 31 pages, 13 figures)

The use of higher strength materials and improved fabricating techniques can result in thinner walls in filament-wound rocket motor cases. Stiffness (resistance to bending deflection) and buckling are thus more likely to be the critical items of design in such structures.

This paper presents design analyses and parametric curves for the two conditions of stiffness and buckling. The analyses consider the orthotropic nature of filament-wound materials. The resulting curves permit selection of the optimum combination of windings for each condition.

A correction factor for use with the theoretical critical buckling stresses is determined from test data.

51113 See Miscellaneous.

51115 See Miscellaneous.

51116 A METHOD FOR MANUFACTURING FOLDABLE REINFORCED CONTAINERS. O. P. H. Dahlke, The Martin Company, Denver, Colorado. No. 2913-63, paper presented at the AIAA Launch and Space Vehicle Shell Structures Conference, Palm Springs, California. April 1-3, 1963
(8 pages, 9 figures)

The principles of the manufacturing methods for foldable tanks were developed by the author. These principles, based on universally recognized manufacturing methods, can be applied for almost all types of pressure vessels or tanks for liquid or solid propellants.

For the purposes of this paper, the manufacturing methods described have reference to a tank with a cylindrical section between two end domes.

51117 ECONOMIC ANALYSIS OF MATERIALS IN CRYOGENIC CONTAINERS. R. W. Temple and R. E. Petsinger, Arthur D. Little, Inc., Cambridge, Massachusetts. and United States Steel Corporation, Pittsburgh, Pennsylvania. No. 2912-63, paper presented at the AIAA Launch and Space Vehicle Shell Structures Conference, Palm Springs, California. April 1-3, 1963
(15 pages, 18 figures, 7 tables)

In an effort to provide the cryogenic industry with a standardized method of comparing economics of cryogenic materials, the United States Steel Corporation developed with Arthur D. Little, Inc., a basis for determination of economic materials of construction. They believe that this scientific undertaking yields practical results in comparing the costs of the vast majority of cryogenic containers.

51118 DESIGN OF A FILAMENT WOUND SEGMENTED MOTOR CASE. J. R. Hinchman and W. D. Humphrey, Thiokol Chemical Corporation, Brigham City, Utah. No. 2918-62, paper presented at the AIAA Launch and Space Vehicle Shell Structures Conference, Palm Springs, California. April 1-3, 1963
(1 reference, 31 pages, 19 figures)

Two concepts for segmenting motor cases are discussed in this paper; the circumferentially-segmented and the longitudinally-segmented (or modular) concepts. The emphasis is placed on the design and fabrication techniques for pinned joints in domes and cylinders, utilizing thin high strength steel strips, bonded between the filament wound fiberglass layers. Also presented is the use of an elastomeric material in areas of high shear stresses. Finally the modular concept with its special dome contour and fabrication problems are evaluated.

51155 See Iron Base.

51170 See Composites.

51192 See Composites.

51199 See Coatings.

51210 See Special Refractories.

Composites

50880 See Miscellaneous.

50921 CERAMIC ADHESIVE-BRAZE ALLOY, COMBINATION TECHNIQUE. D. Brown, The Boeing Company, Wichita, Kansas. Paper presented at the 1963 ASM Western Metal Congress, Los Angeles, California. March 18-22, 1963 (2 references, 23 pages, 17 figures)

Considerable effort has been expended toward developing ceramic or glass adhesives for bonding structures that will be subjected to temperatures higher than present structural adhesives can withstand; the limit now is approximately 500 F.

In order to utilize the best properties of ceramic adhesives and brazing in a single process, it was believed necessary to incorporate a metallic filler or carrier into the ceramic-adhesive bond line. Brazing-type alloys were considered promising for this purpose because of their fusibility at ceramic firing temperatures. Ceramics can be fired in air and strengths are fairly stable over a wide temperature range. The brazing alloy should impart some ductility to the joint.

51048 See Refractory Metals.

51051 See Columbium.

51053 COMPOSITE MATERIAL RESEARCH. F. H. Simpson, The Boeing Company, Seattle, Washington. February, 1963, paper presented at the 7th Meeting of NASA-ASD Refractory Composites Working Group, Lockheed Missiles & Space Company, Palo Alto, California. March 12-14, 1963 (4 pages, 8 figures, 2 tables)

The research at The Boeing Company in 1962 on refractory composite materials is described. Included is a discussion of an ASD sponsored program entitled, "Metal-Ceramic Structural Composite Materials" and, a Boeing Program entitled, "Refractory Metal-Ceramic Macro-Laminate Composites."

51057 MODIFICATION OF PLASMA FLAME IMPINGEMENT TESTER AND SOME PRELIMINARY TESTS OF FOUR COMPOSITE MATERIALS. S. Pan and H. Hahn, Curtiss-Wright Corporation, Wood Ridge, New Jersey. Paper presented at the 7th Meeting of NASA-ASD Refractory Composites Working Group, Lockheed Missiles & Space Company, Palo Alto, California. March 12-14, 1963 (2 references, 8 pages, 17 figures, 3 tables)

An available plasma-jet-materials testing apparatus has been modified and utilized in preliminary evaluation of four composite materials considered for application in rocket engine components.

This apparatus includes a plasma gun, calorimeter, pressure probe and positioning devices.

Several electrode configurations have been evaluated, the most successful of which, in terms of conversion efficiency and durability have been made of pyrolytic graphite. The apparatus, using non-water cooled ring electrodes, is capable of operation for 70 minutes with a heat flux of 4000 BTU/ft^2/sec. at a probe pressure of 19 psi.

51057 (Continued)

Four materials including asbestos-nylon-filled phenolic (Tayloron 5031), silica-fiber-filled phenolic (Fibrite MX 5700), carbon-cloth-mineral-filled phenolic (Fibrite MX 4551) and silica Macro Balloon asbestos (Fibrite MX 2625) were flame impingement tested and evaluated in terms of thermal-erosion resistance, relative insulating properties and other general characteristics.

51069 METHOD FOR DETERMINATION OF THE FREE AND TOTAL TITANIUM CONTENTS IN ZrO_2-Ti COMPOSITIONS. R. W. Moshier and R. Ruh, Aeronautical Research Laboratories, Wright-Patterson Air Force Base, Ohio. ARL 63-13, January, 1963
(4 references, 14 pages, 3 figures, 2 tables)

Procedures have been developed for the determination of the total titanium content and the free titanium content by chemical analysis. Using these procedures the amounts of total titanium and free titanium have been determined in ZrO_2-Ti compositions with 0.38, 1.2, 2.0 and 6.4 weight per cent Titanium. With these data it has been possible to determine the stability of the titanium when present in the free state and in solid solution.

51081 COMPOSITE MATERIALS: AN ANNOTATED BIBLIOGRAPHY. H. M. Abbott, Lockheed Missiles and Space Company, Sunnyvale, California. Report No. 5-10-62-52, Special Bibliography SB-62-58, February, 1963
(89 pages)

This is an annotated bibliography of 190 selected references pertaining to composite materials. Material composites are broadly considered as physical combinations of two or more dissimilar materials. Boron carbide impregnated with aluminum (Boral), metal fibers in glass or plastics, or glass fibers in aluminum are examples of some of the various combinations that are being studied.

Sandwich materials were not included in the search, although few fabricated articles cannot in some way be referred to as composites. Space flight and supersonic aircraft have made great demands for ingenious composites.

The search was completed in September, 1962.

51082 GLASS SURFACE CHEMISTRY FOR GLASS FIBER REINFORCED PLASTICS. A. O. Smith Corporation, Milwaukee, Wisconsin. Progress Report No. 13, April 15, 1963
(7 references, 6 pages, 2 figures, 2 tables)

Bond life studies with Owens-Corning's HTS finish indicated that this finish is comparable to other successful finishes in so far as wet strength retention is concerned. Further bond life tests indicate that aluminum does not have good wet strength retention with the present day finishes. The bond strength test has been modified to the extent that we feel the test can be used to accumulate data on glass surface variations versus bond strength.

51109 See Miscellaneous.

51110 See Applications.

51114 See Miscellaneous.

51121 SOME LIMITATIONS ON HOLLOW GLASS FIBER REINFORCED PLASTICS. A. E. Ketler, Jr., General Electric Company, Philadelphia, Pennsylvania. No. 2923-63, paper presented at the AIAA Launch and Space Vehicle Shell Structures Conference, Palm Springs, California. April 1-3, 1963
(6 references, 9 pages, 8 figures)

A discussion is presented of some of the peculiar factors which place limitations on the application of hollow fiber reinforcements to composite structures. Some of these limitations are associated directly with the hollow filament and composite manufacturing technologies and can be relieved with proper quality control and shrewed process development. Other limitations are related directly to the hollow nature of the fibers and consequently, must be reflected in the design optimization of a structure.

51122 SOME STUDIES ON THE NATURE OF DEFORMATION IN COMPOSITE MATERIALS. J. W. Mar and L. A. Shepard, Massachusetts Institute of Technology, Cambridge, Massachusetts. No. 2924-63, paper presented at the AIAA Launch and Space Vehicle Shell Structures Conference, Palm Springs, California. April 1-3, 1963
(14 references, 18 pages, 14 figures)

A composite material offers the possibility of attaining from two or more components in mechanical combination an optimum synthesis of their properties. Generally, one component is stronger and harder than the other. The manner in which the stronger and harder phase strengthens the weaker or, alternatively, the manner in which the weaker may beneficially affect the behavior of the stronger is the subject of the presentation. Four separate studies are discussed. These are (1) the thin joint in tension, (2) the thin joint in shear, (3) the filamentary composite, and (4) the particulate composite.

51124 BORON FIBER REINFORCED STRUCTURAL COMPOSITES. F. Fechek and M. Hennessey, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio. No. 2926-63, paper presented at the AIAA Launch and Space Vehicle Shell Structures Conference, Palm Springs, California. April 1-3, 1963
(8 pages, 12 figures, 4 tables)

The advent of the aerospace age and its accompanying low density "spaceworthy" structures has resulted in a need for materials which possess specific physical characteristics which were heretofore thought to be unobtainable. Extensive effort is being expended upon research to improve the properties of some of the more conventional materials and develop processes which will enable the utilization of the unique properties of some of the more uncommon materials.

In regard to the latter, boron was chosen as the prime candidate material for study because, in addition to having outstanding physical characteristics relative to the initial criteria, it had previously

51124 (Continued)

been prepared in a pure form by a vapor-deposition technique and had exhibited desirable bulk properties. The vapor deposition technique was considered to be amenable to the formation of continuous lengths of filament, and has proven to be excellent in this regard.

51154 AN INVESTIGATION OF THE MATERIAL PARAMETERS INFLUENCING CREEP AND FATIGUE LIFE OF FILAMENT WOUND LAMINATES. J. W. Dally, Armour Research Foundation of Illinois Institute of Technology, Chicago, Illinois. Department of Navy, 2nd Quarterly Report, August, 1962, AD 282 124, Contract No. NObs-86461
(32 pages, 12 figures, 8 tables)

The objective of the program is to study the behavior of glass-reinforced filament-wound plastics when subjected to compressive states of stress. Specifically, the program consists of two phases, the first of which covers the creep and fatigue behavior of the material under uniaxial compressive stress. The second phase pertains to the creep and fatigue behavior of filament-wound cylinders in biaxial compression. After first establishing the general characteristics of the creep and fatigue effects on composite materials under compressive states of stress, the investigation will be redirected towards a study of the material parameters which influence their physical properties.

51170 PROCEEDINGS OF CONFERENCE ON STRUCTURAL PLASTICS, ADHESIVES, AND FILAMENT WOUND COMPOSITES - VOLUME II - FILAMENT WOUND COMPOSITES. Materials Central, Wright-Patterson Air Force Base, Ohio. Postprint of Conference held at Dayton, Ohio. December 11-13, 1962
(numerous references, numerous pages, numerous figures, numerous tables)

A three day conference on Structural Plastics, Adhesives, and Filament Wound Composites was held. The purpose of the conference was to present recent progress by the Air Force and other government agencies on plastic materials and to review the current state-of-the-art and associated problem areas.

Papers were presented as follows: Preimpregnated Roving, Mandrels, and Designs for Filament Winding, R. Gorcey, Rocketdyne; The Fiberglass Filament Wound Structure (A Correlation of Continuing Studies), R. E. Young, Hercules Powder Company; Intergration of Flaw Detectors in Filament Wound Aerospace Structures, R. A. Burkley, Goodyear Aircraft Company; Vulnerability of Filament Wound Pressure Vessels to Mechanical Damage, J. A. Kies, U. S. Naval Research Laboratory; Optimum Design for Filament Wound Rocket-Motor Cases, F. J. Darms, Aerojet-General Corporation; Sandwich Construction, Filament Wound Rocket Motor Cases, D. H. Wykes, North American Aviation, Incorporated; Manufacturing Technology for Large Plastic Rocket-Motor Cases, R. Hess, Thiokol Chemical Corporation; Design and Qualification Test Procedures for Filament Wound Pressure Vessels, E. E. Morris, Lockheed Missiles and Space Company.

51192 ACOUSTICAL ANALYSIS OF FILAMENT-WOUND POLARIS CHAMBERS. C. S. Lockman, Aerojet-General Corporation, Sacramento, California. Report 0672-01BM-4, Bimonthly Progress Report No. 4, March 25, 1963, Contract No. NOw 62-1007c(FBM)
(8 pages, 8 figures, 3 tables)

51192 (Continued)

The purpose of the program is to investigate the aspects of acoustically analyzing Polaris filament-wound chambers.

This report includes a discussion of the data-presentation and data-evaluation techniques, presents the test data obtained to date for both test objectives, and describes the data-acquisition and playback systems and their application. Results from Phase I testing show that there is a significant relationship between the sounds emanating from a filament-wound chamber during hydrostatic testing and the structural integrity of the chamber. The measured acceleration amplitude (rms) during hydrostatic testing is a function of chamber burst pressure and, as the data show, is inversely related to the burst pressure.

Comparative data for three chambers tested to both the proof and burst pressure demonstrated the sensitivity of the accelerometer techniques of measurement.

The results of Phase II testing show that the velocity of sound in the forward and aft heads and in the cylindrical section of Polaris Model A3X chambers differs (9314, 11, 294, and 10,608 feet per second, respectively). These data also show that the direction of filament-winding and superimposed stress fields does not affect the velocity of sound through a Polaris Model A3X chamber of resin-impregnated E-HTS glass roving.

51202 See Molybdenum.

51206 HIGH TEMPERATURE PROTECTIVE COATINGS DEVELOPMENTS AT GENERAL DYNAMICS/FORT WORTH. P. F. Ghena and J. E. Burroughs, General Dynamics Corporation, Fort Worth, Texas. Paper prepared for the 7th Meeting of the Refractory Working Group, Palo Alto, California. March 11-14, 1963 (13 pages, 2 figures)

The over-all object of the investigation, which has not been realized as yet, is to develop and evaluate a slurry or spray-on intermetallic coating (Sylcor type) for elevated-temperature oxidation protection of refractory-metal alloys subjected to re-entry vehicle environments. The thermal environment considered was 5 hours at 3300 F for the tantalum alloy and 20 hours at 2300 F for the columbium alloy.